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TR 67-50

TECHNICAL REPORT NO. 67-50

INTERIM REPORT NO. 4, PROJECT VT/6703

April 1966 through May 1967

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TECHNICAL REPORT NO. 67-50

INTERIM REPORT NO. 4, PROJECT VT/6703
April 1966 through May 1967

by

LRSM Staff

Availability

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GEOTECH
A TELEDYNE COMPANY
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Garland, Texas

1 September 1967

IDENTIFICATION

The work reviewed in this report was sponsored by the Advanced Research Projects Agency (ARPA), Nuclear Detection Office, ARPA Order No. 624. This research was supported by ARPA under Project VELA-Uniform and accomplished under the technical direction of the Air Force Technical Applications Center under Contract No. AF 33(657)-16270.

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Project Manager:	Mr. R. D. Wolfe, 214 271-2561 Garland, Texas

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ABSTRACT

The progress of the Long-Range Seismic Measurements Program (LRSM) during the period 1 April 1966 through 31 May 1967 is described. The data contained in the report are categorized along the same lines as the organization of the LRSM program; that is, operations, data processing, equipment modifications, equipment and seismogram evaluation, and special projects.

Sixteen mobile observatories and six portable systems were in operation during most of this report period. In January 1967, five of the mobile observatories were moved to Garland, Texas, and maintained on standby basis. The portable systems continued to be used extensively in a wide variety of seismic programs during this report period.

Several equipment modifications were incorporated into the standard system configurations: gas diode lightning protection systems were installed; an improved pen heat circuit w. installed in the portable system Helicorder: ceramic stops were install in the long-period phototube amplifier galvanometers; and the Timing Systems, Model 5400, were replaced in the LRSM vans with Timing Systems, Model 19000. New battery packs and voltage regulators were designed and installed in the portable systems, as well as an electronic voltage sensing circuit. In additior a fire protection system was selected for installation in nine mobile observatories.

The equipment and seismogram evaluation programs continue to advance new and improved methods to ensure high quality data. The resulting data are being used for advanced methods of data processing. A review of the studies and evaluations made is included in this report. Studies have been undertaken and completed by the Special Projects group and include surveys of seismological bulletin data, effects of site geology and source medium on signal and noise properties, and characteristics and methods of processing long-period seismic data.

INTERIM REPORT NO. 4, PROJECT VT/6703
April 1966 through May 1967

1. INTRODUCTION

The Long-Range Seismic Measurements Program (LRSM), a VELA-Uniform project, was first contracted on 1 June 1960. The VELA-Uniform research project is directed towards creating major advances in all areas of seismic detection, identification, and location techniques, to the end that a better understanding of the detection and identification of underground nuclear explosions will be achieved.

The LRSM program has, for nearly 7 years, provided a majority of the detection and recording systems in support of the VELA-Uniform objectives. A large amount of data is presently available on a nonclassified basis for use in various studies by VELA program participants as well as others in the scientific community.

Four technical reports have been written covering the work performed in the LRSM program previous to the time period covered by this report:

a. TR 61-3, Final Report on Phases I, II, and III, Long-Range Seismic Measurements Program, covers work performed from 1 June 1960 through 31 December 1960.

b. TR 62-22, Interim Report on Operating Procedures, Project VT/074, records the LRSM activities from 1 September 1961 through 31 December 1962.

c. TR 66-78, Interim Report No. 2, Project VT/4051, for the period 1 January 1963 through 30 June 1964.

d. TR 66-92, Interim Report No. 3, Project VT/4051, for the period 1 July 1964 through 31 March 1966.

This report describes the work performed during the period 1 April 1966 through 31 May 1967 under Project VT/6703.

LRSM has continued to operate with the same basic purpose described above since 1960. The organizational structure has undergone only minor changes and sustains the flexibility and operating efficiency required for a field-oriented program. Figure 1 shows the organization of the LRSM program on 31 May 1966.

As would be expected, several equipment changes and modifications have been made to the LRSM system. The most notable change in the program has been the increased use of the Portable Seismograph System, Model 19282, in the collection of data for special studies. These operations and other specialized activities are reviewed in this report.

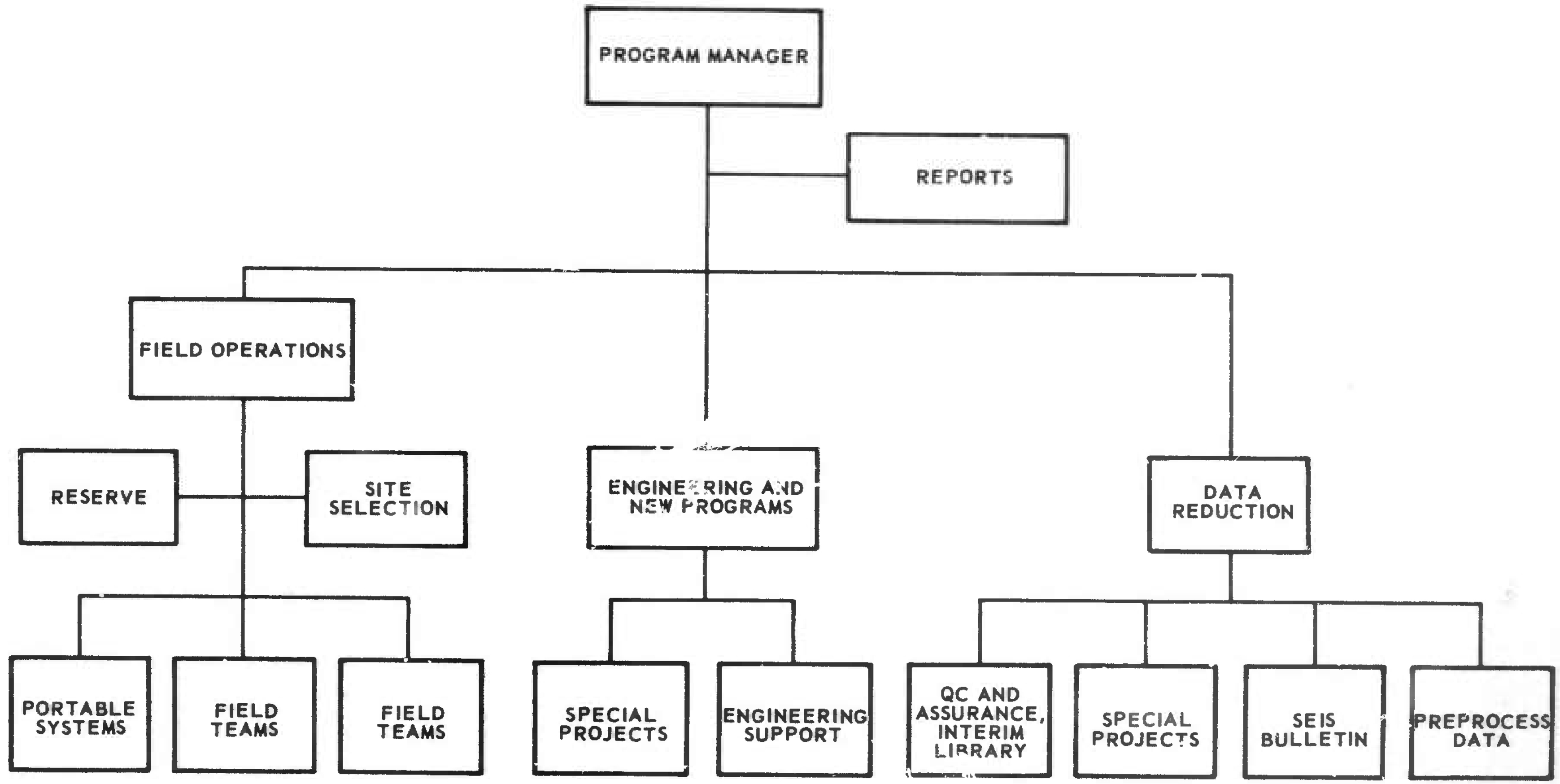


Figure 1. Organization of the LRSM program on 31 March 1966

G 1726

2. SUMMARY

2.1 GENERAL

The operations and technical information in this report (sections 3 through 9) is a comprehensive review of the LRSM program during the specified period. The material is presented so as to best meet the requirements of researchers whose interests are in specific areas of the program: namely, operations, data processing, equipment modifications, equipment and seismogram evaluation, and special projects (data reduction). The following paragraphs in this section summarize the information contained in this report.

2.2 OPERATIONS

Sixteen mobile observatories and six portable systems were in operation during this report period. However, five of the mobile observatories were moved to Garland, Texas, in mid-January and maintained on standby basis. The portable seismographs have continued to provide increased flexibility to the LRSM program. The mobile and portable systems provided support for several projects directly related to the VELA-Uniform program. During this report period, two teams operated a standard mobile seismograph system in abandoned missile complexes near Mountain Home, Idaho and Franktown, Colorado.

2.3 DATA PROCESSING

The processing and reproduction of magnetic-tape data into one of several visual formats are secondary in importance only to the recording of the data. The Special Presentations group added several pieces of equipment to the magnetic-tape laboratory, thus expanding their capability to reproduce data in formats required for routine analysis and special studies.

A special oscillograph was used to transcribe data recorded on magnetic tape by the portable systems to 35 mm film. Over 75,000 feet of film have been processed to date. The device utilizes up to eighteen 5 kc fluid-damped galvanometers, making it possible to record data played back from magnetic tape at X1000 speed. The camera used is a standard 35 mm continuous-strip oscilloscope camera.

Seismological bulletins containing representative data available from the LRSM stations continued to be published monthly. Data are processed from 10 stations each month. Shot reports for events selected by the Project Officer were prepared and distributed upon request. Advanced methods of processing noise study data and data catalog information have been developed.

2.4 EQUIPMENT MODIFICATIONS

Gas diode lightning protection systems have been incorporated into 7 of the LRSM mobile observatories systems and 5 portable systems.

The fluid in the viscous tape supply units for the Ampex Magnetic-Tape Recorder, Model 314, was replaced with fluid of 12,500 centistroke viscosity. This will allow a recommended tension of 8.0 oz for the tape supply reel.

The pen heat circuit for the portable system Helicorder was redesigned and installed to provide better current regulation and increase the stability and reliability of this component.

Ceramic stops were installed in the long-period phototube amplifier galvanometers to prevent the coil from sticking against the limit stops.

The Timing Systems, Model 5400, in the LRSM vans were replaced with all solid-state Model 19000 timing systems. This unit generates a short-period (SP) and a long-period (LP) time program, an automatic weight lift program, and a VELA-Uniform binary coded decimal time program.

The silver-zinc cells used in the portable systems battery packs were replaced with the longer life silver-cadmium cells.

A more flexible portable systems voltage regulator was designed and built during this report period. In addition, an electronic voltage sensing circuit was installed in each portable system battery charger to provide more accurate and positive operation of the charger cutoff relays.

Fire extinguisher systems have been designed for nine of the mobile observatories. One system has been installed and the other eight are being prepared by the vendor for installation.

2.5 EQUIPMENT AND SEISMOGRAM EVALUATION

The quality control checks made on the data recorded on film and magnetic-tape seismograms are the basic and most important work in the LRSM Data Reduction group. The critiques of this data have maintained high quality data and provided valuable information used to improve the data quality. Our critique methods have provided information that can be evaluated with the use of computer programs. This analysis of a large number of critiques has provided information on trends in discrepancies. This information is passed to the field teams and their supervisors for their immediate attention.

2.6 SPECIAL PROJECTS

During this report period a number of special projects and studies were conducted by LRSM geophysicists and engineers. The projects completed were the study of special events monitored by the LRSM portable systems, the investigation of LP signals, and data processing techniques. The results of these projects are reviewed in this report.

3. FIELD OPERATIONS

3.1 GENERAL

The LRSM mobile observatories and portable systems continue to record seismic signals from earthquakes and underground explosions in support of the VELA-Uniform Program. In addition to this, the field teams have continued to be active participants in a series of related programs and experiments. During this report period, the field teams have recorded data from several specially conducted experiments.

Six portable seismograph systems were operating during this report period occupying more than one hundred sites. These teams participated in Projects BLUE ICE, EARLY RISE, ISOLATED ISLAND, and STERLING and recorded detonations from CHASE V and VII, the MONO LAKE series, and GREELEY.

Three array teams were operated during this period. Mould Bay (NP-NT) continued operations of a seven-element array on Prince Patrick Island, Northwest Territory, Canada. One portable system team recorded data from an array of borehole seismometers at the Inge Lehmann station in Greenland. Five portable systems operated an LP array near Payson, Arizona.

3.2 SITE SELECTION ACTIVITIES

One geologist was assigned to select sites and prepare site reports for the program. In this capacity, his duties ranged from map studies of potential locations to land restoration after site deactivation. In addition to landowner and power company negotiations, site selection field work includes land and noise surveys for array sites, preparation of shallow-hole and surface installations, installation assistance, and the collection of data for site reports. Three hundred sixty one sites have been selected for the LRSM program. One hundred five new sites were selected during this report period. Figure 2 shows the sites occupied since 1 April 1966. Table 1 gives a breakdown on distances travelled, days of recording, and number of sites occupied.

There has been no appreciable change in the methods used for LRSM site selection. As in the past, distance and azimuth requirements dominated site location considerations. Given these requirements, isolation from environmental effects, tempered by practical operational objectives, is the major task of the site selector. Usually, a tentative location is advanced by the client, available maps are gathered, and the geologist selects the site in the field. Geographic coordinates for the station locations are taken from maps of the best scale and accuracy available.

The operators of the portable seismograph systems usually select, permit, and prepare their sites. This selection is coordinated with a geologist in the office who aids in location planning and prepares the site reports. If circumstances require additional support, a geologist will select the site in the field prior to the arrival of the portable equipment. This situation arose three times during this reporting period. Sites were selected by a geologist prior to the arrival of equipment when sites at Tonto Forest Seismological

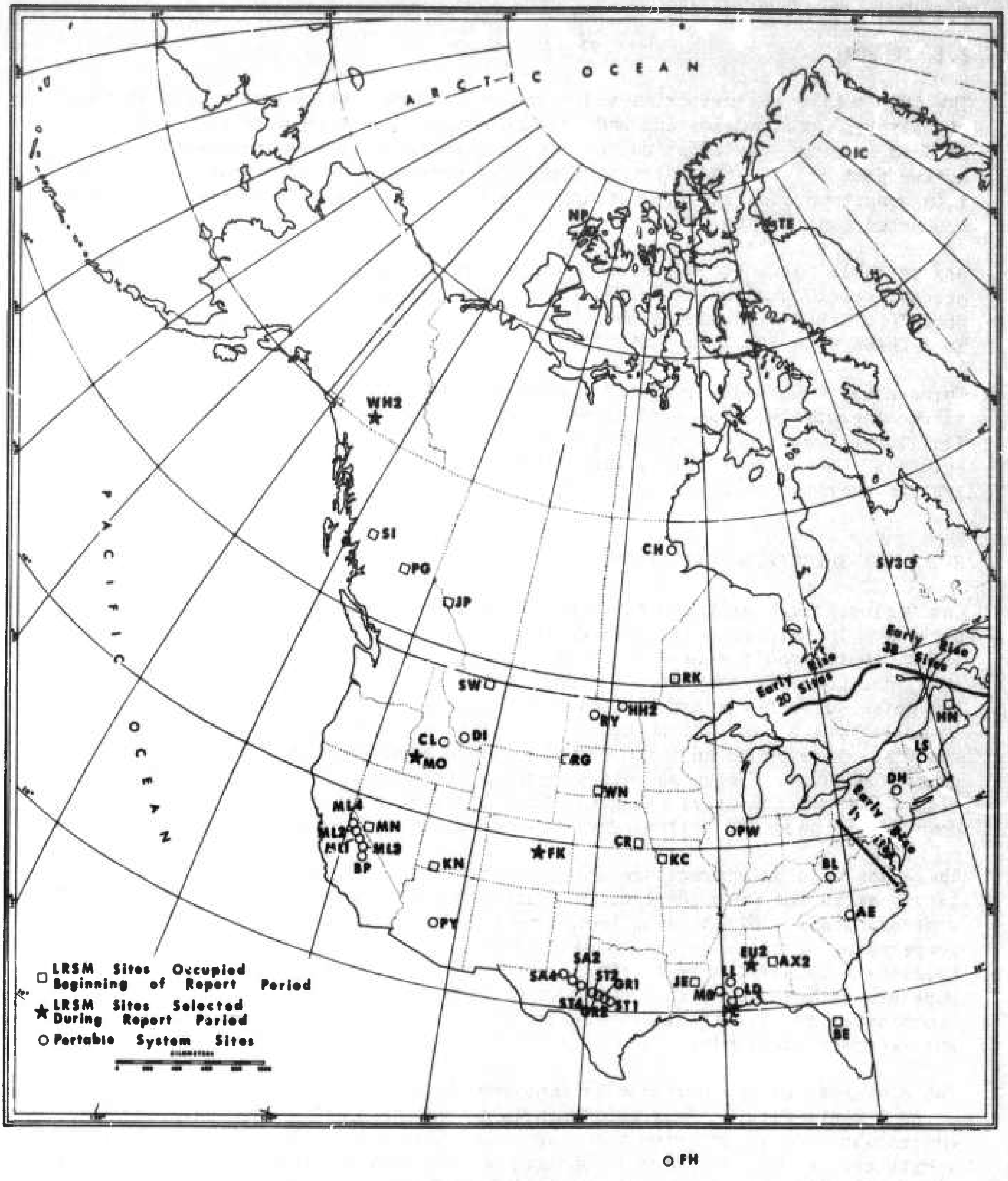


Figure 2. Locations of LRSM sites occupied during the report period, April 1966 through May 1967

G 3057

Table 1. LRSM field operations during April 1966 through May 1967

Type operation	Land miles travelled to occupy	Duration of recording period (in days)	No. of seismometer installations prepared	New sites selected	Sites reoccupied	Total No. of sites occupied
Standard van operations	8500	5578	28	4	2	21
Portable seismograph system	50000	1217	105 occurrences; temporary shelters necessary	99	6	105
Array operations	-	-	26	2	0	3
TOTALS	58500	6795	159	105	8	129

Note: NP-NT, IC-GL, and PY-AZ are the three array sites occupied during this report period.

Observatory (TFSO), central Texas, and southern Mississippi were occupied. In all three cases special rock type or definite directions and distances were required. A total of 105 sites were occupied by the portable systems during this report period, of which 89 were selected by the operators, 12 by geologists, and 6 were old LRSM sites. Seventy-seven of these sites occupied were part of the EARLY RISE project. Tolerance limits of ±5 km from map locations did not always allow isolation of all sites from local noise in selecting the EARLY RISE sites.

The portable seismograph system has increased the capability to occupy sites otherwise inaccessible by the standard LRSM van. These capabilities are not always fully realized, as the operator usually must select and prepare the site in an area which is not the most favorable for recording seismic data. When a limited number of recording days are required, the portable systems are the most practical and economical means of collecting the required data.

3.3 OPERATION OF THE MOBILE OBSERVATORIES

At the start of this report period there were 16 mobile observatories operating in the field. Of these, only Mould Bay (NP-NT) was operating as an array station. There were 11 mobile van moves during this report period. Table 2 lists these moves and the history of the LRSM teams for this period.

No mobile observatories were transferred to other Government agencies or projects during the past 14 months; however, in January 1967, five observatories were retired from the field and moved to Garland, Texas, to be maintained on a standby basis.

3.3.1 A complete retrofit of the Red Lake, Ontario (RK-ON) station was initiated during late summer of 1966. The LP and SP seismometer vaults were relocated. An enclosure which is insulated and heated was built around the vaults. Pictures of the Red Lake (RK-ON) vault retrofit are shown in figures 3 and 4.

3.3.2 In late September and early October 1966, two teams were moved to abandoned missile complexes near Mountain Home, Idaho (MO-ID), and Franktown, Colorado (FK-CO). These teams installed a three-component LP and a three-component SP seismograph in the bottom of a missile silo. A three-component LP seismograph was installed on the surface approximately 100 yards from the silo to provide a comparison with the silo instrumentation. Data from the silo seismographs were recorded on 35 mm film recorders and on magnetic tape. A slow-speed Develocorder was installed at each of the two stations to record data from both LP seismograph installations.

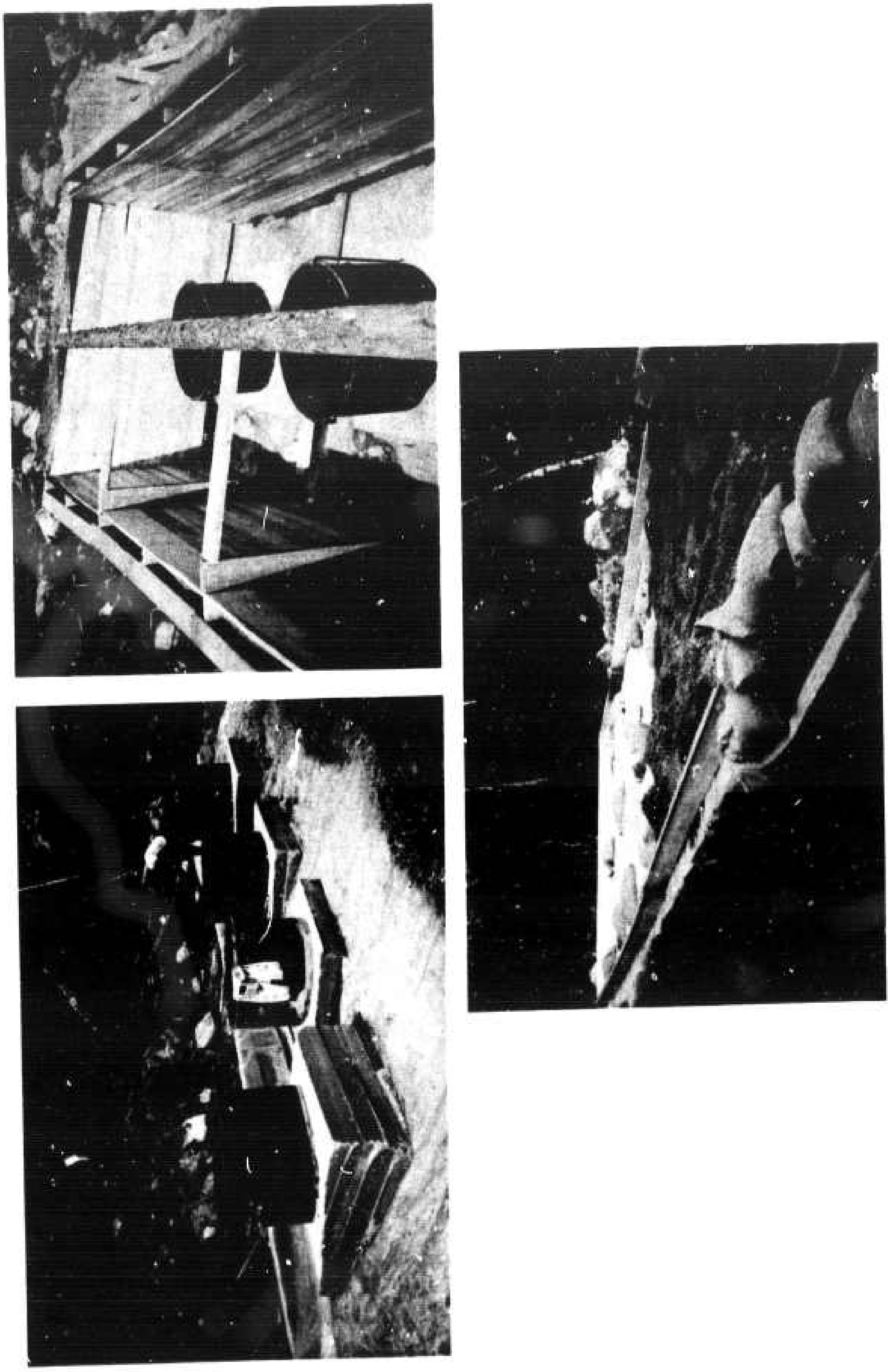
These sites were selected to collect data for an experiment designed to evaluate deactivated missile silos as suitable environments for the operation of LP seismographs. A preliminary analysis of the results of this experiment is given in paragraph 9.3 (c).

The latest proven techniques were employed in preparing the LP seismograph installations, both in the silos and on the surface. Steel tank vaults were installed at the bottom of the silos to provide isolation from atmospheric pressure changes. The vaults on the surface were installed to meet the

Table 2. LRSM mobile team history and moves during the period 1 April 1966 through 31 May 1967

Team	Site location	Designator	Date arrived	Date operational	Date closed
3	Red Lake, Ontario	RK-ON	21 June 63	17 July 63	-
8	Schefferville, Quebec	SV2QB	15 Sept 65	13 Oct 65	-
11	Kanab, Utah	KN-UT	19 Nov 61	21 Dec 61	-
13	Mould Bay, Canada	NP-NT	27 June 63	23 Aug 63	-
*15	Belleview, Florida	BE-FL	12 Sept 65	17 Oct 65	16 Jan 67
	Garland, Texas	GL-TX	25 Jan 67	-	-
*16	Kansas City, Mo.	KC-MO	24 Sept 65	27 Oct 65	16 Jan 67
	Garland, Texas	GL-TX	24 Jan 67	-	-
18	Houlton, Maine	HN-ME	09 Aug 62	23 Aug 62	06 Sept 66
		Van destroyed by	fire 06 Sept 66		
*21	Alexander City, Ala.	AX2AL	07 Mar 66	24 Mar 66	16 Jan 67
	Garland, Texas	GL-TX	31 Jan 67	-	-
*27	Smithers, B. C.	SI-BC	15 Oct 65	07 Nov 65	14 Oct 66
	Whitehorse, Yukon	WH2YK	27 Oct 66	24 Nov 66	-
28	Prince George, B. C.	PG-BC	15 Oct 65	01 Nov 65	-
*30	Sweetgrass, Montana	SW-MA	13 Sept 65	16 Oct 65	13 Sept 66
	Houlton, Maine	HN-ME	30 Sept 66	25 Oct 66	-
*33	Jasper, Alberta	JP-AT	13 Oct 65	23 Oct 65	14 Sept 66
	Mt. Home, Idaho	MO-ID	27 Sept 66	17 Nov 66	-
35	Mina, Nevada	MN-NV	12 Sept 61	10 Oct 61	-
*36	Redig, S. Dakota	RG-SD	14 Oct 65	07 Nov 65	26 Sept 66
	Franktown, Colo.	FK-CO	04 Oct 66	17 Nov 66	-
*37	Crete, Nebraska	CR-NB	14 Oct 63	01 Nov 65	14 Oct 66
	Jena, Louisiana	JE-LA	25 Oct 66	16 Nov 66	16 Jan 67
	Garland, Texas	GL-TX	26 Jan 67	-	-
*38	Winner, S. Dakota	WN-SD	14 Oct 65	25 Oct 65	14 Oct 66
	Eutaw, Alabama	EU2AL	26 Oct 66	12 Nov 66	16 Jan 67
	Garland, Texas	GL-TX	03 Feb 67	-	-

* Teams which moved



G 3058

Figure 3. Red Lake, Ontario (RK-ON) vault retrofit

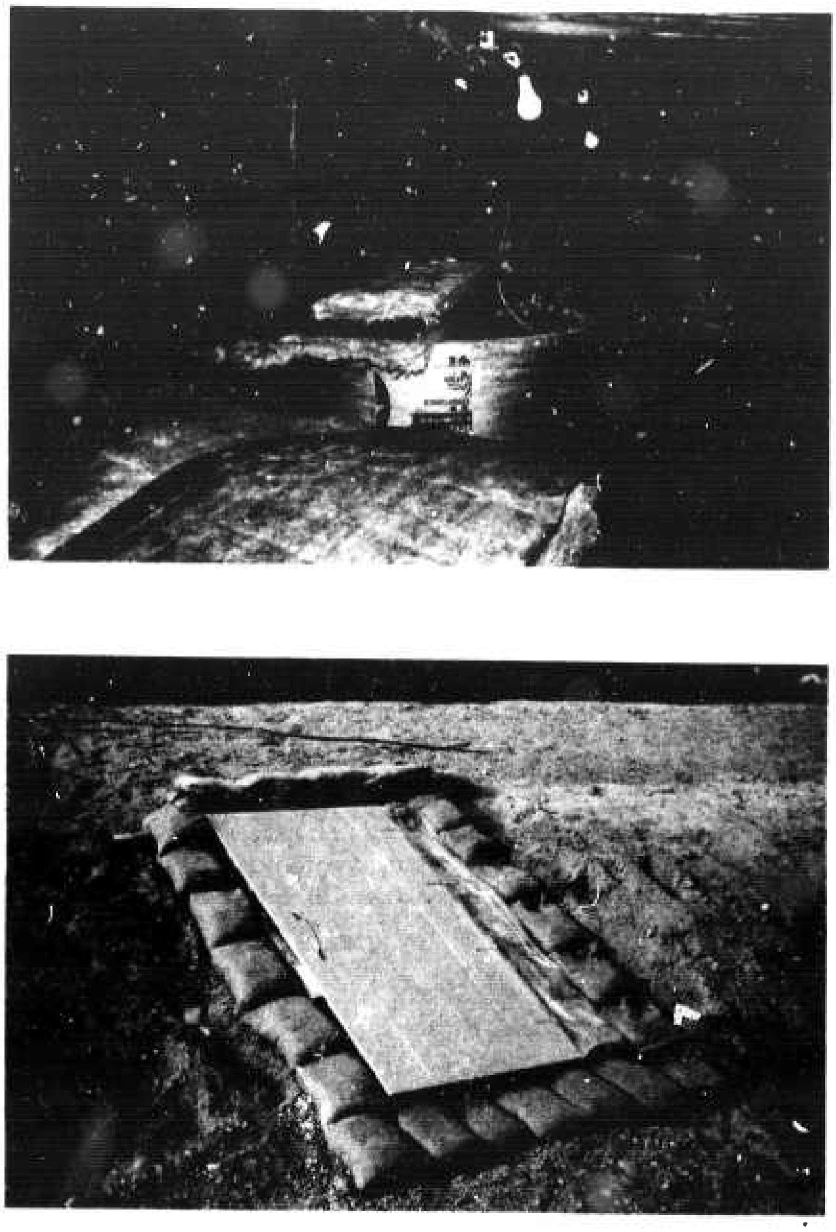


Figure 4. Red Lake, Ontario (RK-ON) vault retrofit

G 3059

present standards for all LRSM vault installations. The same model vault was used in both the silo and the surface installations and all vaults were sealed.

The MO-ID observatory was equipped with multiconductor cable which was used on the silo instrumentation; the standard spiral-four cabling was used with the surface LP instruments. The FK-CO observatory used spiral-four cabling throughout their installation. Figures 5 and 6 show views of the FK-CO and MO-ID sites. A cross section of a missile silo is shown in figure 7.

3.3.3 On 6 September 1966, the van and all van-mounted equipment at Houlton, Maine (HN-ME), were destroyed by fire. The local fire inspector concluded that the source of the fire was in the magnetic-tape system blower motor. The cause was very likely overheating of the motor brought about by a momentary power failure. The Sweetgrass, Montana (SW-MA), site was closed in late September, and this observatory was moved to Houlton, Maine, to re-establish that site. Appendix 1 is a list of all equipment and tools destroyed by the fire.

3.3.4 An automatic fire extinguisher system was designed for the vans shortly after the Houlton fire. In May 1967, a prototype system was installed at the FK-CO site. Similar systems are being prepared in kit form and will be installed in eight of the other vans during September 1967. This system will not be installed at the NP-NT site.

3.3.5 Mina, Nevada (MN-NV), and Kanab, Utah (KN-UT), operated an additional seismograph system in support of a special study for Lawrence Radiation Laboratory (LRL). During special recording periods, these teams operate a SP vertical seismograph recording data on a four-channel high-speed 35 mm film recorder. Each channel is adjusted to an assigned magnification. Copies of the standard LRSM SP vertical 35 mm film and logs are also supplied to LRL.

3.3.6 The Sweetgrass, Montana (SW-MA), station was vandalized twice during June and July 1966. On each occasion the phototube amplifier shelter was entered; cables were cut, the electronic equipment was stolen or destroyed, and paint was thrown on the exterior of the van. The Federal Bureau of Investigation and local authorities were notified of each incident. Investigations were conducted, but the results were inconclusive.

3.4 OPERATION OF PORTABLE SYSTEMS

The six portable system teams recorded data at 105 sites during this report period. Seventy-seven of these sites were occupied during Project EARLY RISE in July 1966. The portable teams recorded signals from CHASE V and VII, MONO LAKE, and GREELEY detonations, and participated in Projects BLUE ICE, ISOLATED ISLAND, EARLY RISE, and STERLING.

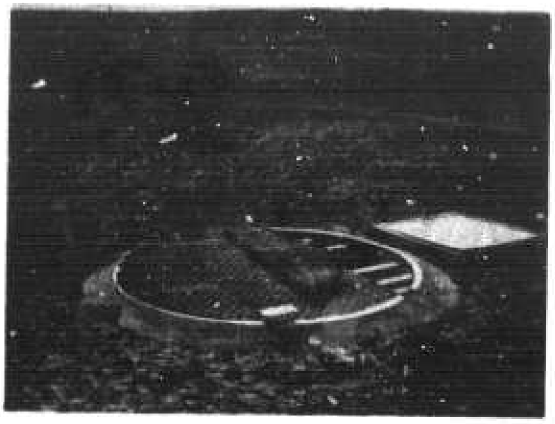
The portable system teams have demonstrated their ability to become operational in a minimum amount of time. The average time required to set up the three-component SP and three-component LP systems is 56 man-hours. The SP instrumentation, with complete calibrations, can become operational in 16 man-hours. If the requirements are such, the SP instruments can become operational within 3 hours without complete set-up calibrations.

View of LP vaults on the basal silo slab

Figure 5. Franktown, Colorado (FK-CO) site

G 3060

View west from fence toward surface long-period vaults at arrow



View of propellant terminal which was used as a cable entrance to silo. Power terminal is to right of propellant terminal

View of long period vault installation and short-period seismometers

View south toward entrance to complex from silo No. 2

Figure 6. Mountain Home (MO-ID) site

G 3061

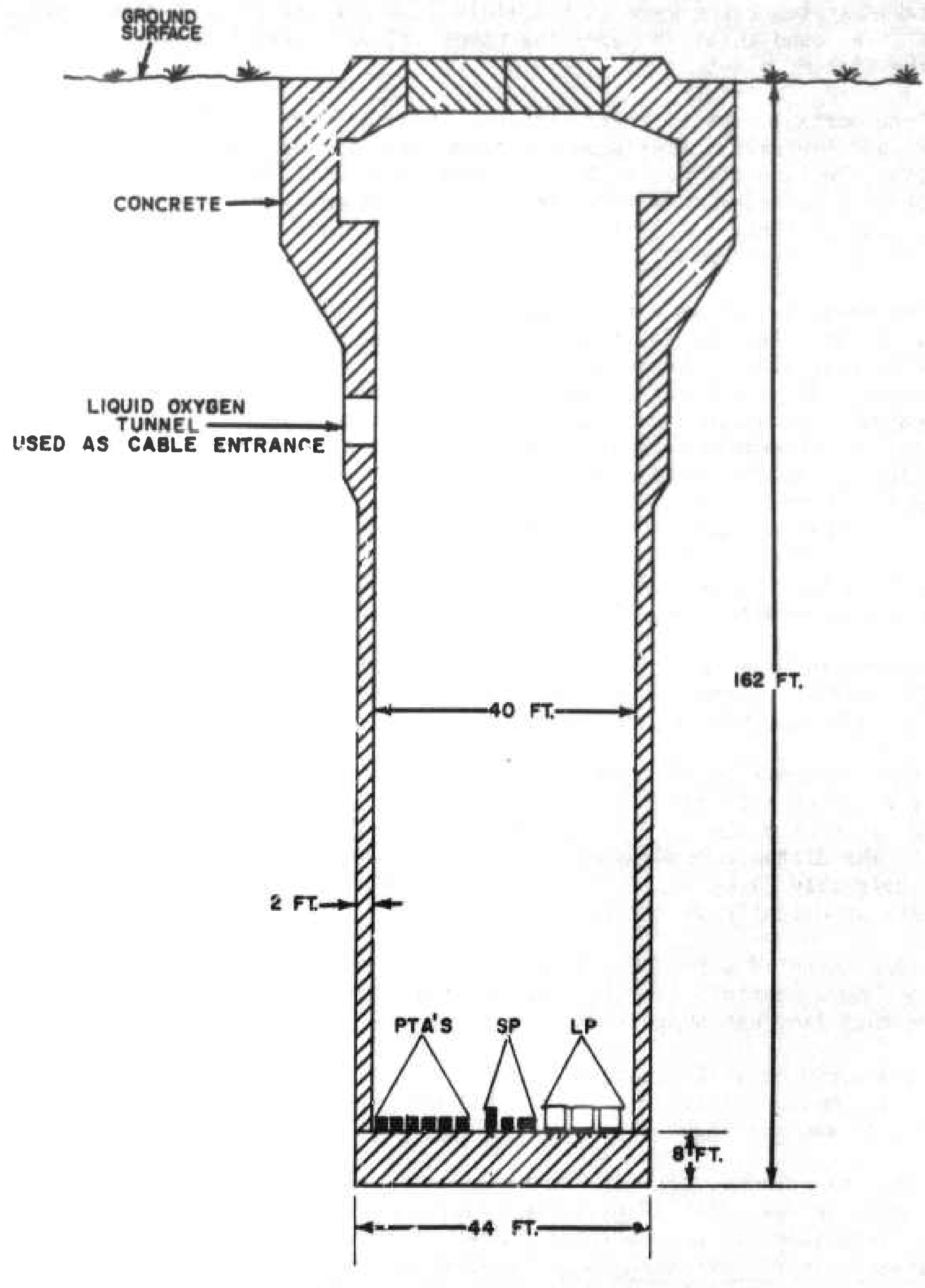


Figure 7. Generalized cross section of a missile silo

G 3062

The portable system teams were in the field 73.5 percent of this report period. Figure 8 is a graph which compares the number of days each team was in the field and in the Garland plant.

3.4.1 Four portable system teams recorded SP data from the CHASE V event. The personnel and equipment comprising two teams were transported by commercial air from Dillan, Montana (DI-MA) to Beckley, West Virginia (BL-WV), and from Challis, Idaho (CL-ID), to Delhi, New York (DH-NY). Two teams were transported by contract vehicle to their respective sites in Ryder, North Dakota (RY-ND), and Hannah, North Dakota (HH2ND).

3.4.2 One portable system was assigned to Project BLUE ICE to perform a noise study at the Inge Lehmann station on the Greenland Ice Cap. Figure 9 shows the location of this site. The setup of the portable system at this station began 24 June 1966. The initial instrumentation was comprised of a three-component SP seismograph system installed in an ice-block bunker near the surface. Four SP borehole seismometers were installed to form a triangular array with 1 seismometer located in the center, approximately 9038 feet from the other 3 borehole instruments. Each borehole seismometer was operated at an approximate depth of 195 feet. A three-component LP seismograph became operational on 29 April 1967, replacing the three-component surface SP system. The portable system is being operated on a loan basis to Arctic Institute of North America, who operates the station under the direction of Air Force Office of Scientific Research (AFOSR).

3.4.3 During the summer of 1966, one portable system team participated in the ISOLATED ISLAND experiment. This team recorded seismic data from both SP and LP seismographs and acoustical data.

3.4.4 Four portable system teams were assigned to record data from Project EARLY RISE during a 21-day period from 7 July through 28 July 1966. One system occupied sites on a line extending from Chibaugamou, Quebec, to Chapleau, Ontario. The distance between each of the 20 recording locations on this line was approximately 30 km. This line was designated as ER1 and the sites were designated numerically as ER101, ER102, etc.

Two systems occupied sites on a line extending from Chibaugamou, Quebec, to Glace Bay, Nova Scotia. The distance between each of the 38 recording locations on this line was approximately 30 km. This line was designated as ER2.

One system occupied sites along a line extending from East Liverpool, Ohio, to South Mills, North Carolina. Distance between each of the 19 recording stations on this line was approximately 30 km. This line was designated as ER3.

During this experiment, each of the teams selected and prepared one site daily and recorded SP data from 77 different locations. Figures 10, 11, and 12 show the site locations on each of these lines. Technical Report No. 66-116, Participation in Project EARLY RISE, Long-Range Seismic Measurements Program, is a detailed review of this data collection effort.

3.4.5 Between 2 September and 9 September 1966, a series of 12 high-explosive shots were detonated at a single point in the waters of Mono Lake, California. The shots were monitored by four of the portable systems. The purpose of the series was to establish whether any differences exist in the energy releases

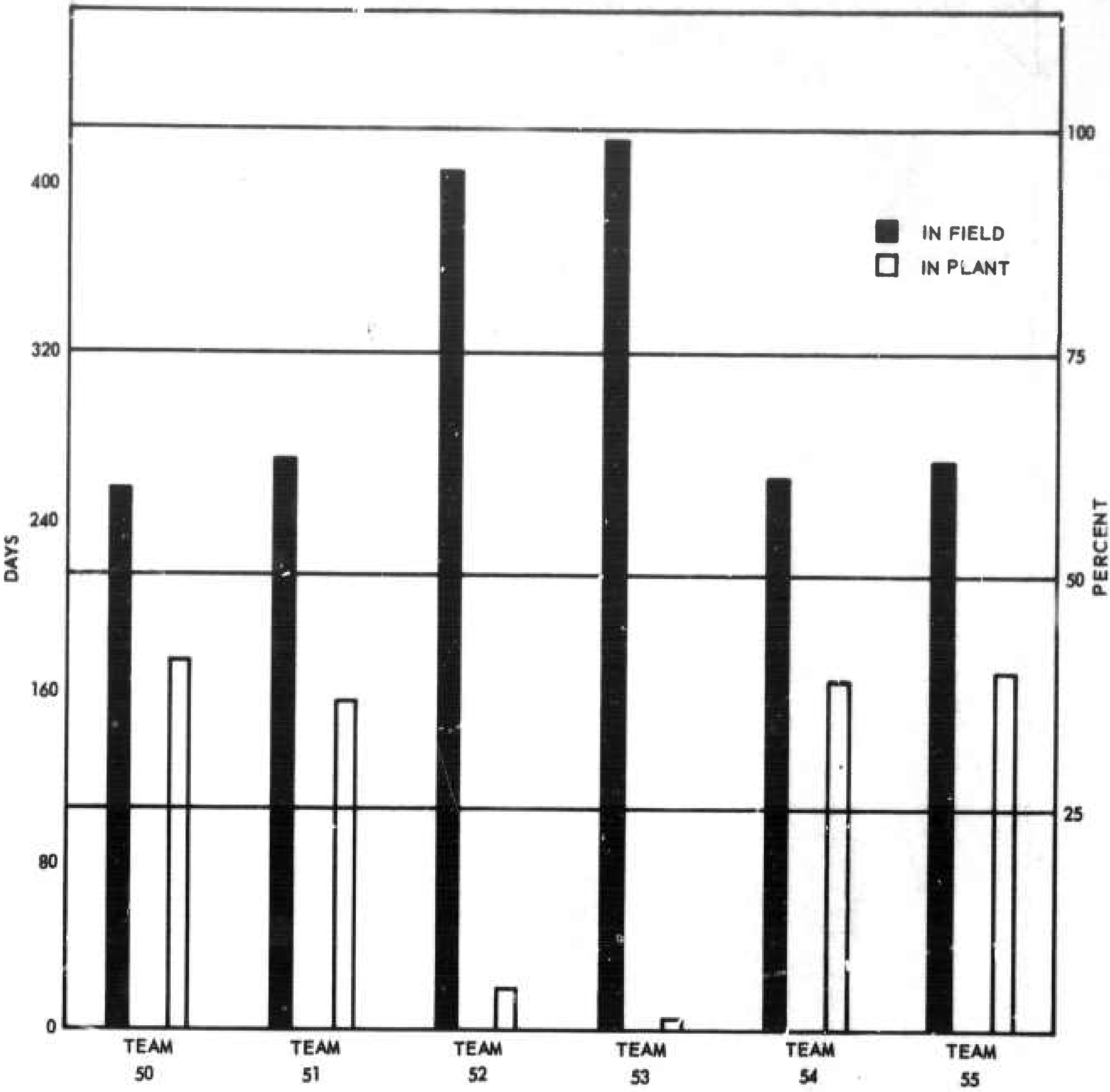
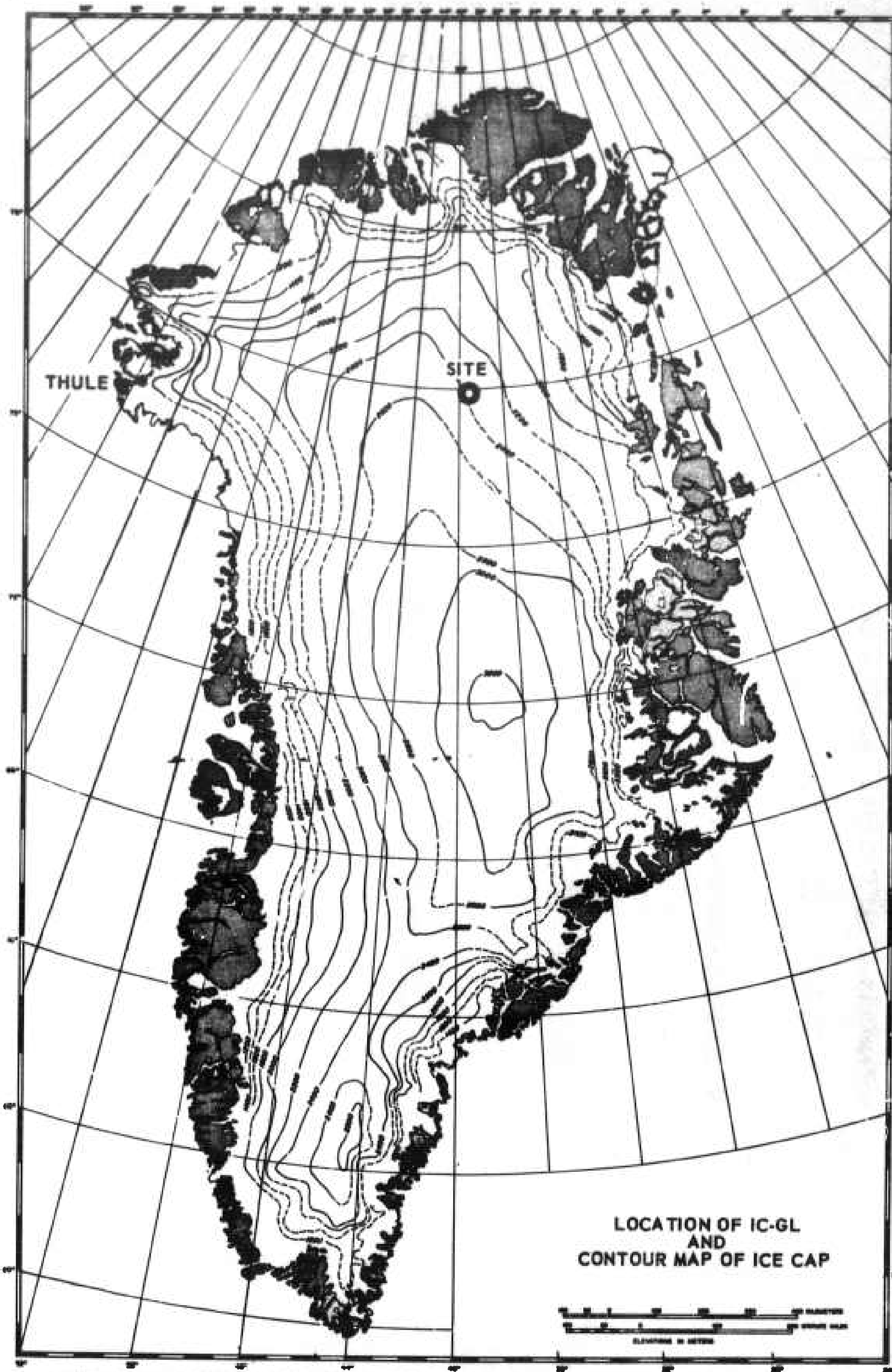


Figure 8. Portable system teams operations for period 1 April 66 through 31 May 67

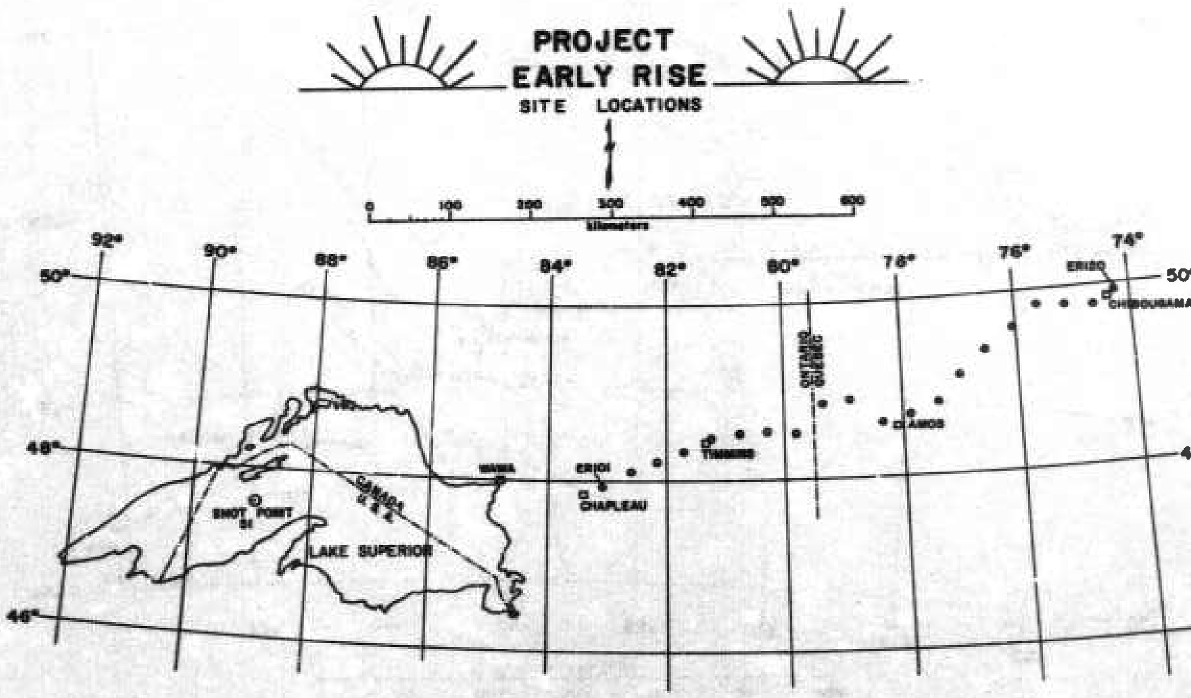
G 3063



SOURCE: COLD REGIONS RESEARCH AND ENGINEERING LABORATORY RESEARCH REPORT 170.

Figure 9. Greenland Ice Cap Array

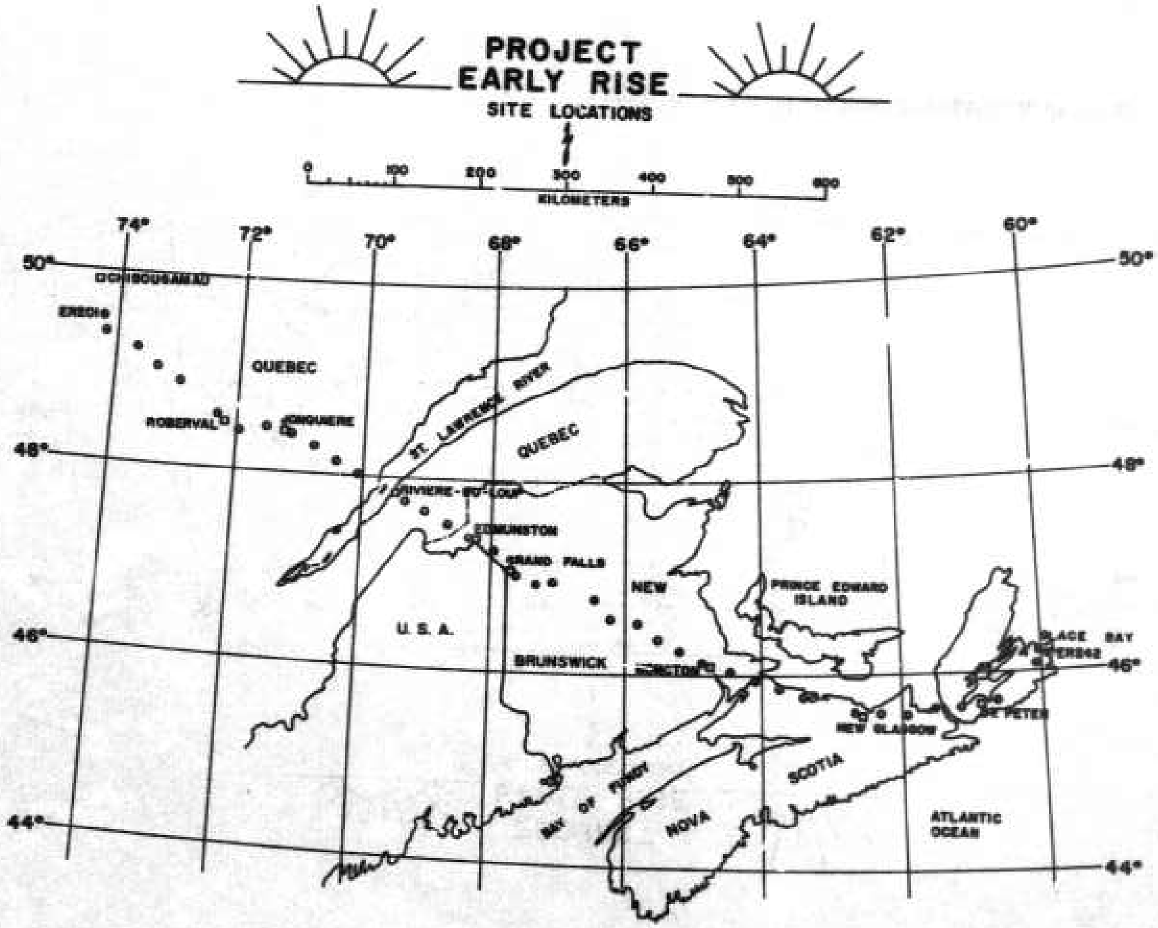
G 3064



Date June, 1966	Site	Coordinates Lat. N.	Long. W.	Distance to Shot Point (kilometers)
7	ER120	49°55'29"	074°15'30"	1108
8	ER119	49°47'26"	074°38'17"	1082
9	ER118	49°49'14"	075°07'41"	1047
10	ER117	49°49'25"	075°36'00"	1014
11	ER116	49°35'29"	076°01'36"	979
12	ER115	49°22'52"	076°32'16"	939
13	ER114	49°07'19"	077°00'24"	902
14	ER113	48°50'10"	077°25'13"	868
15	ER112	48°41'47"	077°54'14"	831
18	ER111	48°37'2[illegible]"	078°18'38"	801
19	ER110	48°51'49"	078°51'49"	764
20	ER109	48°47'51"	079°21'26"	726
21	ER108	48°32'00"	079°51'51"	686
22	ER107	48°32'19"	080°16'39"	655
23	ER106	48°32'18"	080°46'05"	619
24	ER105	48°29'16"	081°16'14"	582
25	ER104	48°20'16"	081°45'15"	544
26	ER103	48°13'35"	082°10'10"	512
27	ER102	48°06'07"	082°36'13"	479
28	ER101	47°55'47"	083°08'11"	437

Figure 10. Site locations from Chibougamau to Chapleau

G 3065

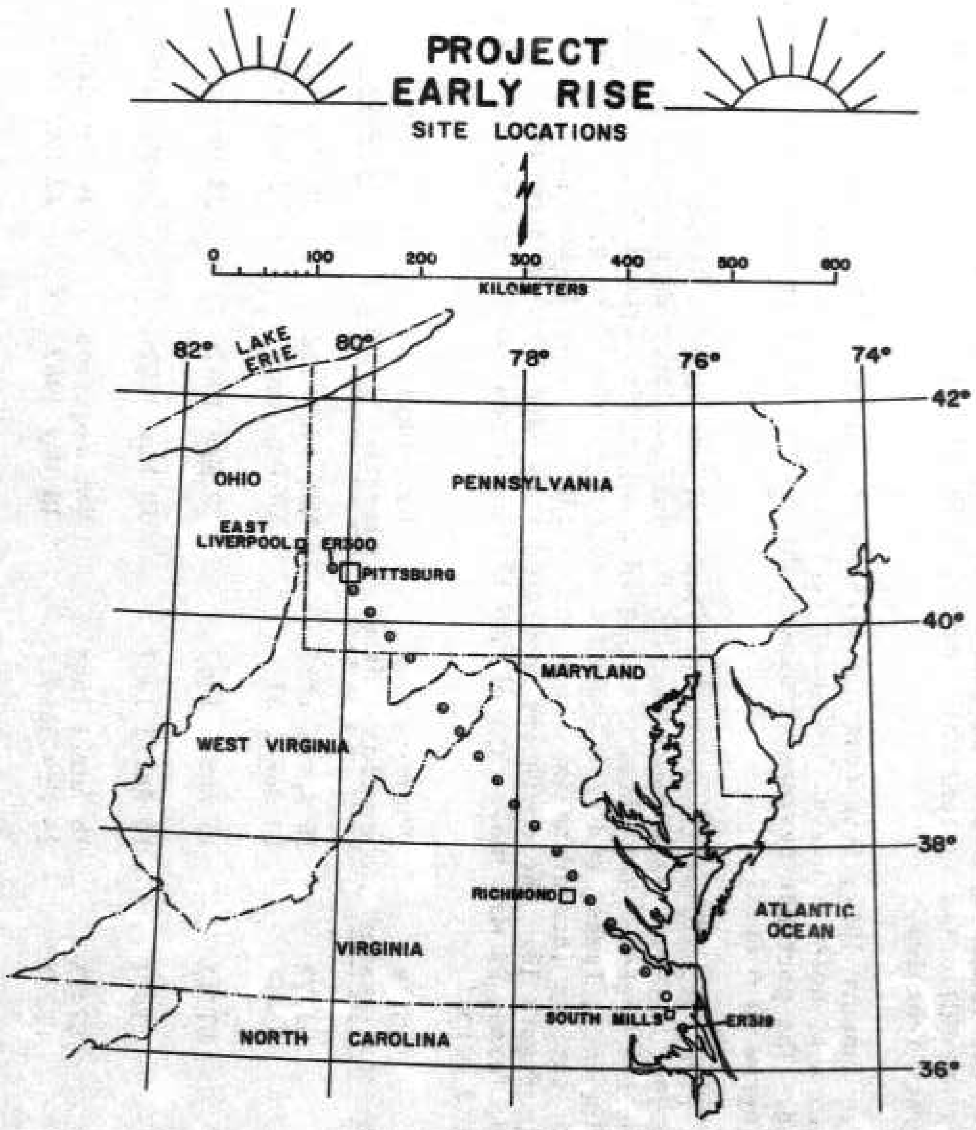


June, 1966	Site	Coordinates Lat. N	Long. W.	Distance To Shot Point In Kilometers
7	ER201	49°35'41"	074°16'38"	1102
7	ER202	49°21'12"	074°02'17"	1117
8	ER203	49°11'09"	073°40'18"	1145
8	ER204	49°02'24"	073°21'48"	1167
9	ER205	48°52'29"	072°56'01"	1197
10	ER207	48°33'23"	072°20'44"	1241
10	ER208	48°24'35"	071°58'36"	1269
11	ER209	48°29'08"	071°36'14"	1295
11	ER210	48°20'41"	071°08'47"	1330
12	ER211	48°16'33"	070°47'52"	1356
12	ER212	48°10'21"	070°17'35"	1395
13	ER213	48°00'54"	070°04'22"	1413
14	ER215	47°48'16"	069°25'23"	1463
14	ER216	47°37'38"	069°00'35"	1496
15	ER217	47°29'11"	068°39'48"	1524
15	ER218	47°24'17"	068°20'30"	1549
18	ER219	47°13'05"	067°55'00"	1584
18	ER220	47°01'03"	067°43'40"	1602
19	ER221	46°54'44"	067°21'53"	1632
19	ER222	46°52'50"	066°58'34"	1662
20	ER223	46°48'48"	066°36'48"	1689
20	ER224	46°35'32"	066°13'[illegible]6"	1723
21	ER225	46°32'18"	065°50'47"	1753
21	ER226	46°20'13"	065°35'42"	1777
22	ER227	46°11'46"	065°09'45"	1813
22	ER228	46°08'51"	064°54'21"	1833
23	ER229	46°00'54"	064°31'16"	1866
23	ER230	45°58'07"	064°10'27"	1893
24	ER231	45°52'00"	063°49'11"	1923
24	ER232	45°44'56"	063°26'55"	1955
25	ER234	45°35'32"	062°42'53"	2014
25	ER235	45°35'55"	062°18'02"	2045
26	ER236	45°34'56"	061°54'16"	2075
26	ER237	45°37'35"	061°33'30"	2100
27	ER238	45°37'26"	061°13'12"	2126
27	ER239	45°39'42"	060°50'21"	2154
28	ER241	46°01'41"	060°12'22"	2189
28	ER242	46°09'38"	059°56'12"	2206

NOTE: Sites ER206, ER214, ER233 and ER240 were not occupied.

Figure 11. Site locations from Chibougamau to Glace Bay

G 3066



Date June, 1966	Site	Lat. N.	Long. W.	Distance to Shot Point In Kilometers
7	ER300	40°27'42"	080°10'50"	1052
8	ER301	40°17'13"	079°56'58"	1082
9	ER302	40°04'42"	079°46'13"	1109
10	ER303	39°52'31"	079°31'50"	1140
11	ER304	39°41'45"	079°15'49"	1169
12	ER306	39°15'10"	078°54'43"	1227
13	ER307	39°02'01"	078°39'11"	1259
14	ER308	38°49'47"	078°26'08"	1290
15	ER309	38°37'20"	078°13'54"	1319
18	ER310	38°22'35"	078°03'20"	1349
19	ER311	38°09'52"	077°48'50"	1382
20	ER312	37°57'28"	077°35'36"	1411
21	ER313	37°44'17"	077°25'51"	1439
22	ER314	37°31'29"	077°11'09"	1471
23	ER315	37°17'47"	076°57'55"	1503
24	ER316	37°05'18"	076°45'18"	1533
25	ER317	36°52'52"	076°34'55"	1561
26	ER318	36°38'08"	076°21'34"	1594
27	ER319	36°23'27"	076°09'51"	1627
28	ER319	36°23'27"	076°09'51"	1626

NOTE: Site ER305 was not occupied.

Site ER319 was occupied for two days. The difference in the distance to the shot point is because of the changing shot point location.

Figure 12. Site locations from East Liverpool to South Mills

G 3067

of seismic signals from four types of explosives. The map in figure 13 shows the locations of these teams during the Mono Lake shot series. A review of the results of data analysis is contained in paragraph 9.2 (a).

3.4.6 Four portable systems were operated on sites in a ring of approximately 68 km radius from the shot point of Project STERLING. Prior to the STERLING explosion, a tamped 4000 lb chemical explosion was set off near the SALMON cavity for calibration purposes. The calibration shot was detonated on 17 November 1966. The STERLING shot was detonated in the Tatum Salt Dome in Mississippi on 3 December 1966. Figure 14 is a map showing site locations for the teams participating in this project. A report of the data analysis from the STERLING explosion is contained in paragraph 9.2 (c).

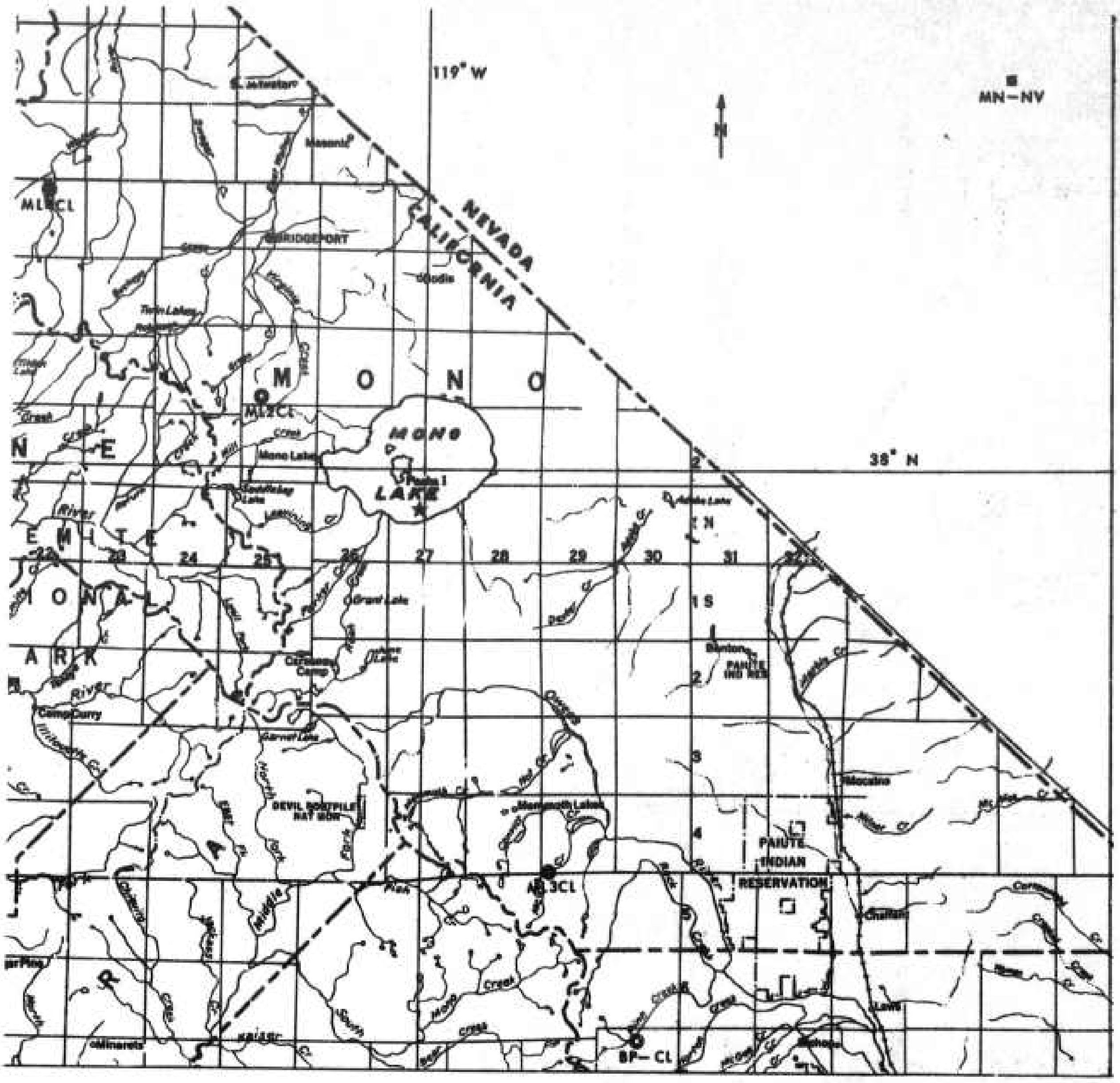
3.4.7 One portable system operator established a site near Fort Sherman, Panama Canal Zone (FH-PM), in early November 1966 in support of the GREELEY explosion. This station discontinued operations after the GREELEY event and returned to Garland, Texas, near the end of December 1966.

3.4.8 The four portable systems operating in Mississippi for Project STERLING were moved to new sites for the GREELEY shot. Two systems were transported by air to reoccupy sites near Thule, Greenland (TE-GL), and Churchill, Manitoba (CH-MT); one system was assigned to reoccupy the Lisbon, New Hampshire (LS-NH), site; and the remaining system operated a new site near Albemarle, North Carolina (AE-NC). The systems which occupied LS-NH and AE-NC were transported by contract vehicles.

3.4.9 In January 1967, five portable systems were assigned to Project VT/5055 to aid in a LP noise study at TFSO near Payson, Arizona. SP data were not recorded. The portable systems completed their work and were reassigned to the LRSM program on 6 April.

3.4.10 Five portable system teams operated stations in West Texas during April and May 1967. These teams recorded data for surface layer experiments in the Llano Uplift region. The sites were placed along a line from Streeter, Texas, to Garden City, Texas, and were spaced at approximately 80 km along this line. The two stations located on the south end of the line were 10 km apart, as shown in figure 15. The operators completed this experiment and returned to Garland, Texas, 25 May 1967. The SP and LP operational dates of each team are tabulated below:

Team No.	Site designator	Short-period operational date	Long-period operational date	Site closed
50	SA2TX	15 April 1967	Not required	16 May 1967
50	SA4TX	18 May 1967	18 May 1967	23 May 1967
51	ST1TX	15 April 1967	19 May 1967	23 May 1967
53	ST2TX	16 April 1967	19 May 1967	23 May 1967
54	ST4TX	16 April 1967	Not required	16 May 1967
54	GR2TX	19 May 1967	19 May 1967	23 May 1967



○ PORTABLE
■ LRSM SITE
★ MONO LAKE SHOT POINT

SCALE
0 10 20 30
Kilometers

Figure 13. Locations of LRSM systems recording the Mono Lake shot series

G 1674A

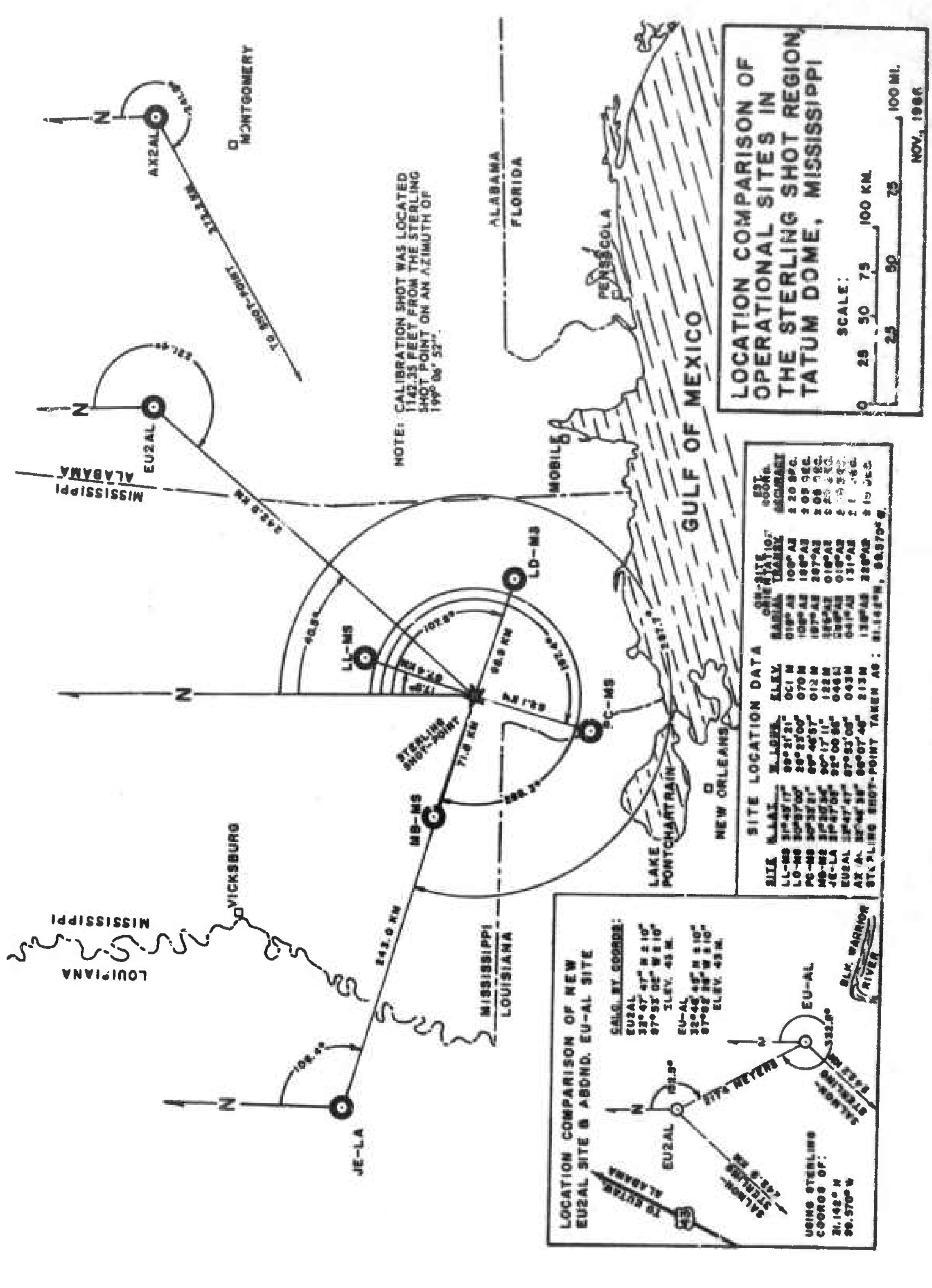
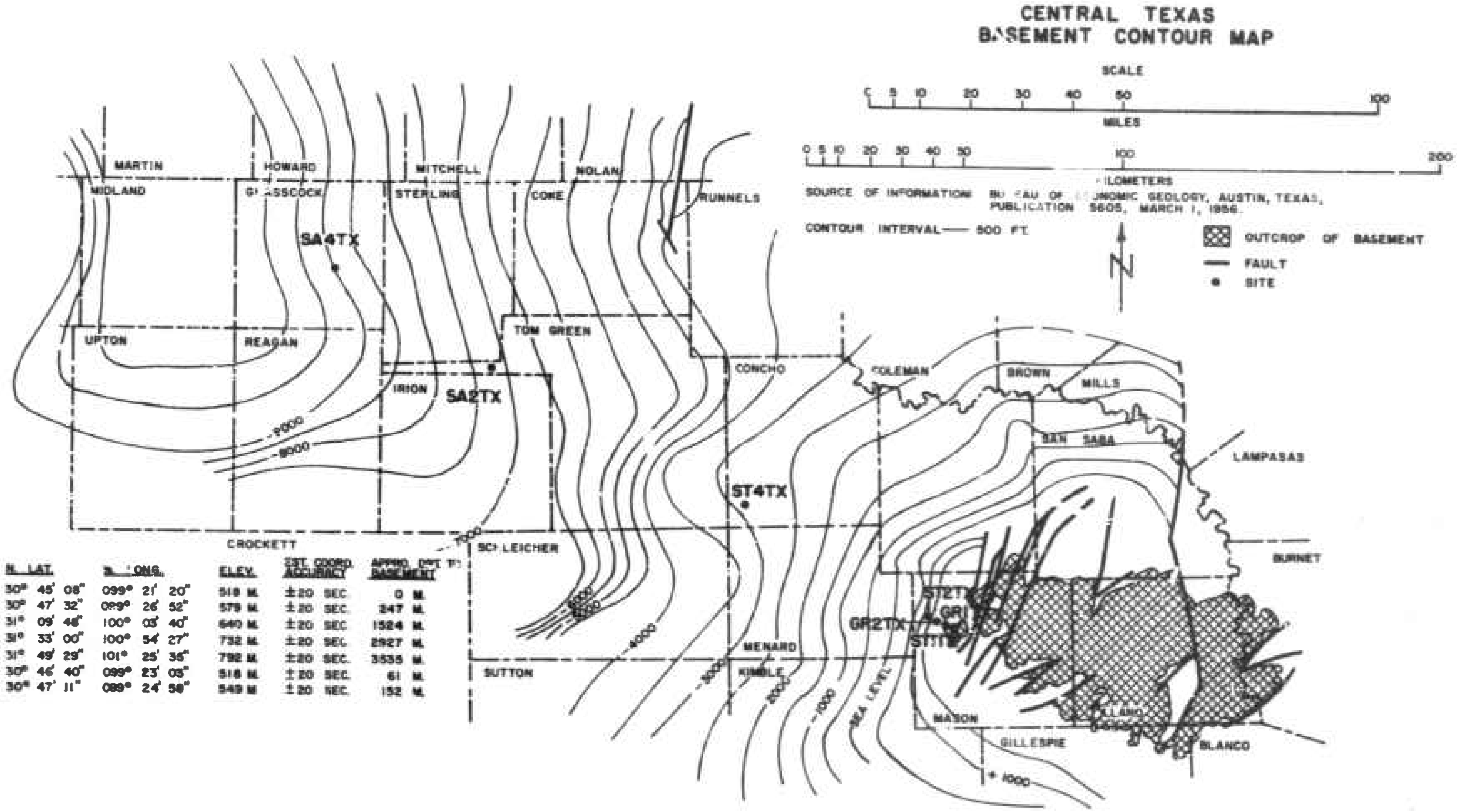


Figure 14. Site locations of participating teams during Project STERLING



SITE	N. LAT.	W. LONG.	ELEV.	EST. COORD. ACCURACY	APPRO. DPT TO BASEMENT
ST1TX	30° 45' 08"	099° 21' 20"	518 M.	±20 SEC.	0 M.
ST2TX	30° 47' 32"	099° 26' 52"	579 M.	±20 SEC.	247 M.
ST4TX	31° 09' 48"	100° 03' 40"	640 M.	±20 SEC.	1524 M.
SA2TX	31° 33' 00"	100° 54' 27"	732 M.	±20 SEC.	2927 M.
SA4TX	31° 49' 29"	101° 25' 35"	792 M.	±20 SEC.	3535 M.
GR1TX	30° 46' 40"	099° 23' 03"	518 M.	±20 SEC.	61 M.
GR2TX	30° 47' 11"	099° 24' 58"	549 M.	±20 SEC.	152 M.

Figure 15. Locations of LRSM systems recording data for the Llano Uplift studies

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Team No.	Site designator	Short-period operational date	Long-period operational date	Site closed
55	SA4TX	17 April 1967	Not required	8 May 1967
55	SA2TX	9 May 1967	Not required	16 May 1967
55	GR1TX	19 May 1967	19 May 1967	23 May 1967

A summary of the preliminary findings of this study is in paragraph 9.2 (d).

4. EVALUATION OF STANDARD AND MODIFIED INSTRUMENTATION

4.1 GENERAL

The major equipment of the LRSM seismographs, both mobile and portable, is discussed in this section. The results of special tests are also included.

4.2 SEISMOMETERS

4.2.1 Benioff Vertical Seismometer, Model 1051, and Benioff Horizontal Seismometer, Model 1101

These seismometers continued to give very good service with only an occasional problem from condensation, fungus growth, or oxidation. These problems were solved by following a routine maintenance program.

4.2.2 Portable Vertical Seismometer, Model 4681A, and Portable Horizontal Seismometer, Model 6102A

These seismometers continued to perform with good reliability. Only occasional maintenance was required to clean and inspect the signal output connector.

4.2.3 Portable Seismometer, Model 18300

This short-period seismometer is the detector for the portable seismograph system and has given very good service. Maintenance on these units is required only after damage is incurred by abusive handling during shipment.

4.2.4 Long-Period Sprengnether Seismometer

Environmental conditions continued to be the primary consideration associated with the placement and operation of the Sprengnether LP seismometers. Improved performance has been obtained through upgraded vault installation standards and the use of the one-piece (excluding lid) steel vault.

4.2.5 Vertical Long-Period Seismometer, Model 7505A, and Horizontal Long-Period Seismometer, Model 8700C

These seismometers are used in the portable systems. The weight and size of these instruments are inconsistent with the concepts of the high degree of

portability and fast reaction time which are essential to the effectiveness of the portable systems. The units gave satisfactory service, with loss-of-magnet-field-strength being the most frequent problem. An improved magnet and coil assembly is presently under evaluation.

4.2.6 Johnson-Matheson Vertical Seismometer, Model 6480

This seismometer continued to give satisfactory service at NP-NT. Frequent maintenance and adjustments were required because of the extreme temperature variations encountered at this site.

4.2.7 Electro-Film Vault Heater

An Electro-Film blanket-type vault heater, consisting of a 115 Vac, 50-watt insulated lattice of heating elements designed to fit the contour of a vault lid, was tested at KN-UT. The test results indicated no detectable improvement in the operating characteristics of the LP test seismograph which used this vault heater over the performance of a seismometer heated by an incandescent light bulb. Since incandescent bulbs are considerably more economical to use than the Electro-Film heaters, no action was taken to purchase these heaters for the program.

4.2.8 Bendix Flexure Pivots

Flexure pivots, manufactured by the Utica Division of the Bendix Corporation, were evaluated for use in long-period seismometers. This type of flexure has been used successfully in short-period detectors. Careful inspection and testing of the flexures have revealed that the concentric components in some of the flexures have reacted eccentrically, and a careful selection of the flexures for application in long-period seismometers will be required. The procedures for testing each flexure do not present a significant problem and if the selection of these pivots proves to be economically feasible, it is expected that they can be utilized in the LRSM program. A LP Seismometer, Geotech Model 8700A, was modified for the installation of these flexures and will be field tested during the fall, 1967. The Bendix flexure is shown in figure 16.

4.2.9 Remote Control Motors for Long-Period Seismometers

Problems of corrosion, fungus growth, and condensation were experienced in the LP seismometer remote control motors. These problems were reduced by placing desiccant in the units and sealing the outer covers with silicone rubber. Sealed motors were considered, but were rejected because of the high cost. The modified control units are shown in figure 17.

4.3 AMPLIFIERS

4.3.1 Phototube Amplifier, Model 4300, and Phototube Amplifier, Model 5240

These amplifiers are used in the SP and LP systems, respectively, at the mobile observatory sites. They continued to perform satisfactorily, requiring only routine maintenance.

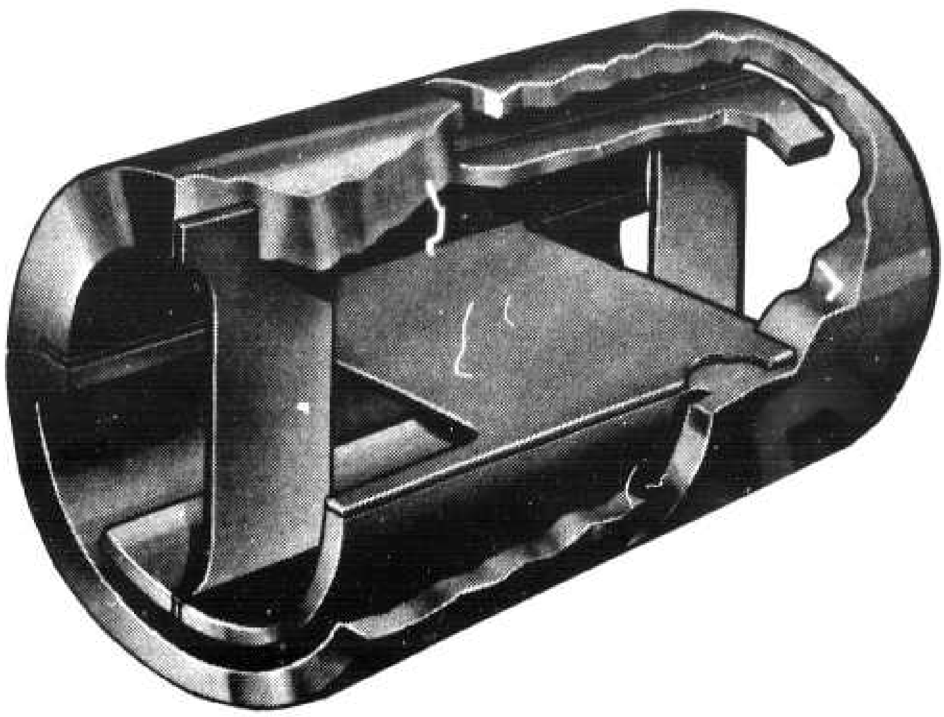

Figure 16. Bendix flexure pivot

G 3070

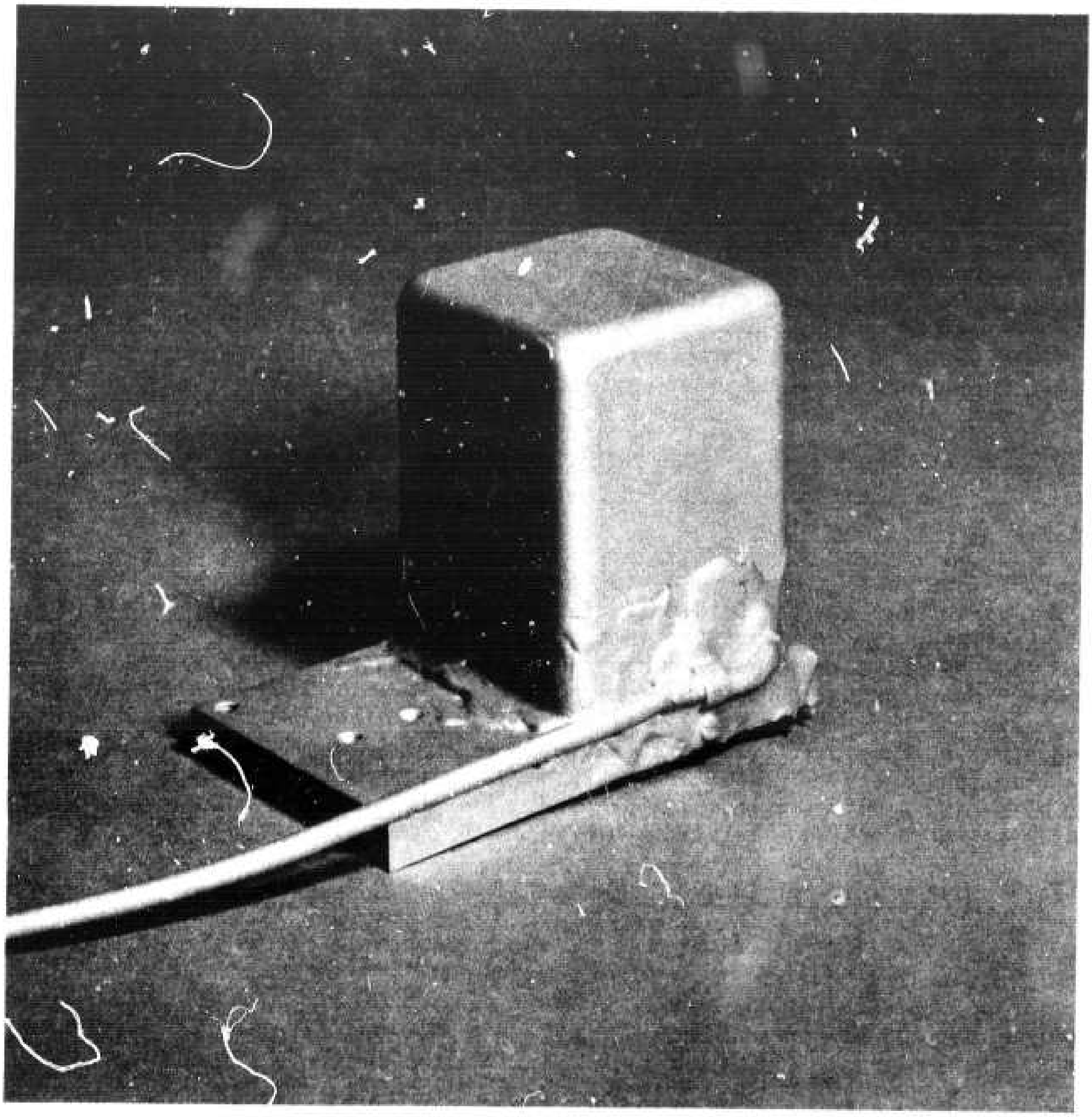

Figure 17. Remote control motor for long-period seismometers

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4.3.2 Amplifier and Control Unit, Model 23927, and Amplifier and Control Unit, Model 23928

The Model 23927 SP amplifier and control unit and Model 23928 LP amplifier and control units are used in the portable seismograph system. The amplifiers employ photocells and rugged galvanometer suspensions which enable the units to be transported commercially with little danger of damage. The units provide line termination, amplification, response shaping and control of signals from 3 SP and 3 LP seismometers. The following problems were encountered:

a. Difficulty in maintaining galvanometer balance;

b. Troubleshooting difficulty due to the compact packaging.

Satisfactory operation of the units was obtained as the portable system operators became more familiar with the critical adjustment characteristics of the units. These photocell amplifiers will be replaced with solid-state amplifiers in future portable seismograph systems.

4.4 DATA LINES

4.4.1 Spiral-Four Cable

Spiral-four cable, a four-conductor shielded cable, continued to give satisfactory service as the field cable for the mobile observatory teams. The cable lengths have been standardized so that they may be shipped as kits with the connectors installed, thus reducing site set-up time. All cables between the recording van and the vaults are 660 feet long. Cables between the recording van and the PTA shelter are 100 feet long. The cable lengths between the PTA shelter and the vaults were not standardized as they do not have connectors. At stations where the above lengths are not sufficient, two or more sets of cables or 1/4 mile sections can be used. The spiral-four cable requirements at a standard mobile observatory are shown in figure 18.

4.4.2 Belden Foil-Shield Two-Conductor Cable

Belden 8761 Belfoil Miniature Broadcast cable was selected as a substitute for the Belden Type 8422 Cable (used in the vans and PTA shelters) whenever this cable is replaced for any reason. The Belden Type 8761 cable was selected because of its superior fatigue failure rate and its 100 percent shielding characteristics.

4.5 LIGHTNING PROTECTION

4.5.1 Carbon Block and Fuse Protection

The carbon block and fuse protection system of lightning protection remained in service at WH2YK, PG-BC, NP-NT, RK-ON, MO-ID, MN-NV, KN-UT, and SV3QB, and as discussed in the Interim Report No. 3 (TR 66-92), continued to give adequate protection during most thunderstorms. A program of periodic cleaning and checking of the protectors is required in order to maintain data quality.

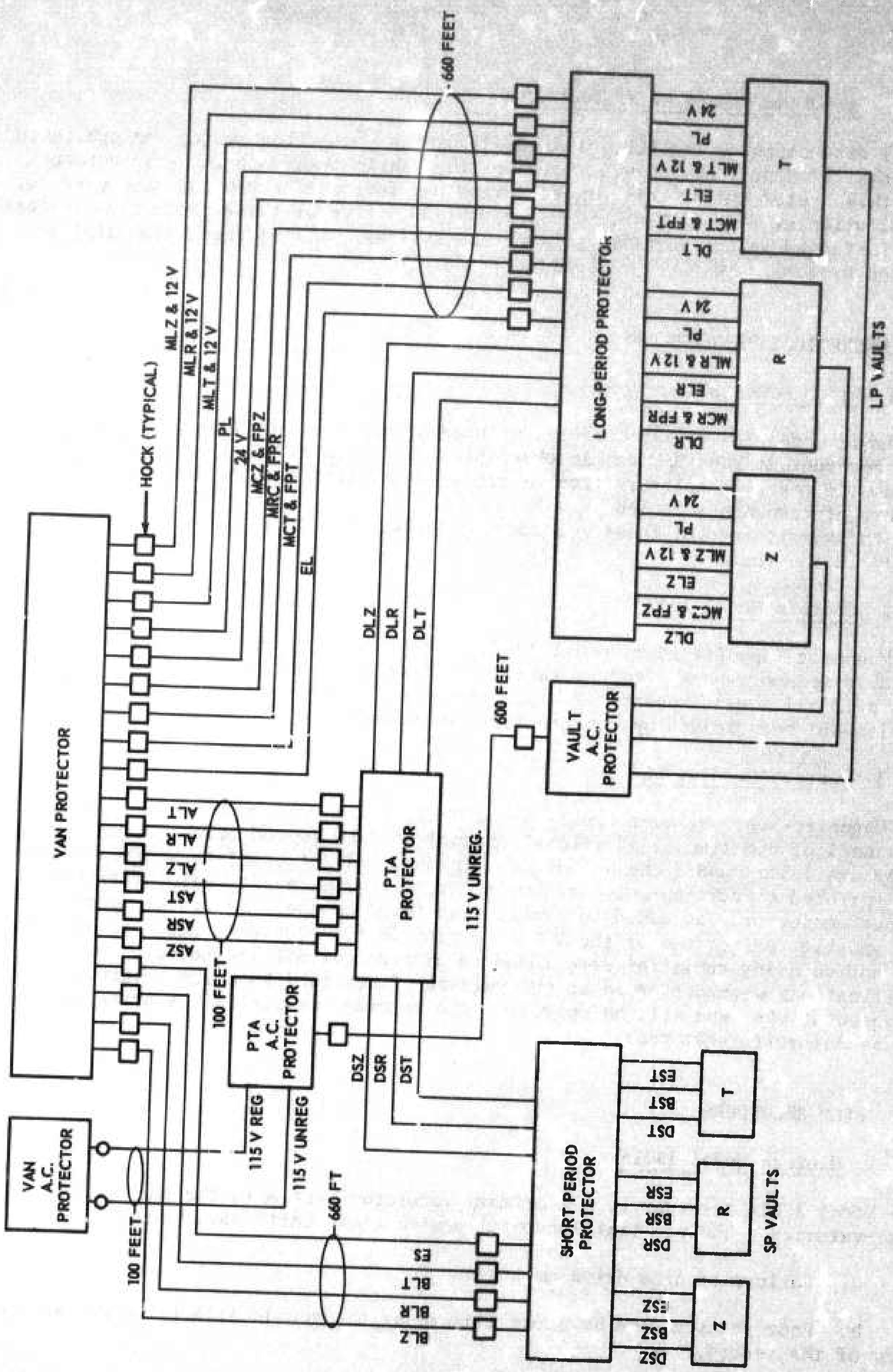


Figure 18. Field cabling at standard mobile observatories

4.5.2 Gas-Diode Lightning Protection

A full discussion of the AEI gas-diode lightning portection system was published in Technical Report No. 66-92. Seven of the mobile observatories were equipped with this system during this report period and four more are being assembled for installation at SV3QB, MN-NV, KN-UT, and RK-ON. Five of these protection systems were installed in the portable seismograph systems. All of these lightning protection systems have given reliable service.

4.6 MAGNETIC-TAPE RECORDERS

4.6.1 Ampex Model 314

The Ampex Model 314 tape recorder continues to serve as the primary magnetic-tape recorder at the LRSM mobile observatories. Maintenance has become difficult because of the long delivery time of replacement parts and the increased rate of failure of components caused by the lengthy time in service. It is anticipated that the maintenance of these recorders will become increasingly difficult and costly in the future.

4.6.2 Geotech Model 19429

The Magnetic-Tape Recorder, Model 19429, the primary recorder for the LRSM portable seismograph system, operated satisfactorily with no major problems arising. Infrequent reports of high system noise have been made, but this problem has been solved by conscientious maintenance.

4.6.3 Geotech Model 17554

The Magnetic-Tape Recorder, Dual-Speed, Model 17554, was modified to provide 1 channel of BCD time, 1 additional channel of data reproduction (2 were originally available) and 1 channel of BCD reproduction. A complete reproduce channel (printed circuit cards, card connector, wiring harness, selector switch and output connector) was added to provide the third channel. A direct record card was substituted for one of the VCO's to provide for recording BCD. An AM detector and squaring amplifier were added to provide for BCD reproduce. These modifications were performed at the request of Stanford Research Institute representatives, who will be operating the recorder as part of an Array System in the Antarctic next year.

4.7 FILM RECORDERS

4.7.1 Geotech Model 1301A

The Model 1301A recorder is the primary recording system in the LRSM mobile observatories. The problems encountered with these units have been:

a. Failure of drum drive mechanism;

b. Poor focus caused by loose film or by the double film thickness at the ends of the record.

A program of more complete drum repair, when maintenance is required, was initiated in an attempt to alleviate the problems with the drive mechanism. A thinner, more flexible film was tested for a possible solution to the record problem. The film development speed is faster than desirable for field operations and further tests will be required to determine its acceptability. Geotech has discontinued the 1301A recorder as a standard product: therefore, a longer lead time will be required for replacement parts that are not available in LRSM stock in the future.

4.7.2 Develocorder, Geotech Model 4000C

This recorder has been used at stations which require additional data recording channels for arrays and special study stations. During this report period, Develocorders were operated at FK-CO, MO-ID, and NP-NT. The units used at MO-ID and FK-CO were modified to record LP data at a recording speed of 3 mm/min. The general performance has been satisfactory with occasional problems arising in the processing units and film drive mechanisms. A rigid schedule of maintenance has reduced the number of occurrences of these problems.

4.7.3 Develocorder Film Evaluation

Five types of film were tested with various combinations of developers, developer concentrations, temperatures, light intensities, and film transport speeds. The film now being used (Kodak 7457727A) was included as a basis of comparison. The four new films were Kodak SO-266, Kodak SO-336, Bell and Howell MD-1, and Bell and Howell MD-8. Preliminary test results indicate that the Kodak SO-336 film gave the best results. A more extensive evaluation is planned during the next contract period.

4.8 HELICORDERS

4.8.1 Geotech Model 2484

This recorder is used in all mobile observatory systems, primarily as a troubleshooting aid and occasionally as an auxiliary recorder during special periods of interest. Two analog data traces with a time reference are recorded on heat-sensitive paper mounted on a drum. The recorders operated with a minimum of routine maintenance. The most frequent problem was that of broken stylii.

4.8.2 Geotech Model 12400

This recorder is used in the Service Recorder, Model 19820, as an aid in the calibration and servicing of the portable systems. One channel of analog data with a time reference is recorded on heat-sensitive paper mounted on a drum.

The performance of this unit has been acceptable except for the pen heat circuit, which originally had poor current regulation. This problem was corrected by a redesign of the circuit and no problems have been reported following the incorporation of this modification. Additional information regarding this modification is contained in paragraph 7.3.2.

4.9 TIMING SYSTEMS

4.9.1 Geotech Model 5400-M2

This system was discontinued as the primary source of station timing for the mobile observatories. These units required an increasing amount of maintenance and their reliability was poor. A program of replacement of these systems with the Model 19000 timing system was begun in September 1966 and completed in December 1966. NP-NT was not included in this program and this station continues to use the Model 5400-M2. A large supply of spare parts is available at NP-NT for the Model 5400-M2 and it is expected to continue to give satisfactory service.

4.9.2 Geotech Model 19000-01-04

The integration of the Model 19000 timing systems into the mobile observatory systems was completed in December except as noted in the previous paragraph and now serves as the primary station timing in both the mobile and portable seismograph systems. After a few minor problems following the new installations in the recording vans, the systems have performed satisfactorily with only an occasional failure.

4.9.3 Geotech Model 19000-01-02

These timing systems are operated in the portable systems. During the report period, they operated with no major problems.

4.9.4 Radio Receivers

a. General Coverage Receivers. The general coverage receivers that are used in the recording vans continue to operate satisfactorily with routine maintenance. These receivers are:

1. Hammarlund SP-600
2. Collins 51J3
3. Hallicrafter R-274
4. Motorola R-390

b. Gertsch Model 1910. This receiver is a special unit designed to receive United States standard time broadcasts only. Six of these units have been in operation in the portable systems since September 1965 with no major problems.

c. Specific Products, Model WVTR. This unit has operated in the prototype portable system (Team 50) for 3 years with no major problems. Two improved versions of the receiver have been obtained, one being operated in a mobile recording van and the other used in the Antarctic Array System. This unit is designed to receive time broadcasts only and is expected to replace the Gertsch Model 1910 in future applications. The operational specifications of the improved version match those of the Gertsch receiver and are lower priced.

4.10 CALIBRATION

There were no changes made in the seismograph calibrators and the evaluations discussed in the previous interim report remain applicable.

4.11 POWER SYSTEMS

4.11.1 Nicad Batteries

The nickel-cadmium battery banks used in the LRSM van systems continued to be a reliable source of dc power, with only preventive maintenance being required. Lubrication of terminal posts, proper level and specific gravity of the electrolyte, and the presence of a layer of oil to prevent evaporation of the electrolyte are the important points checked under the preventative maintenance program.

4.11.2 General Radio Regulator

This regulator continued to provide a reliable source of voltage-regulated 115 Vac power for the magnetic-tape recorders in the mobile observatory systems.

4.11.3 Inverter, Model 10050A

This inverter continued to serve as a satisfactory source of 115 Vac, 240 cps frequency-regulated power for the PTA's.

4.11.4 Batteries for Portable Systems

The silver-zinc batteries of the Power Source, Model 19824, failed at the end of their "shelf life" and were replaced by silver-cadmium batteries in five of the portable systems. One set of silver-zinc batteries had been purchased just prior to the time the decision was made to change to the silver-cadmium type and this set remain in service.

The change of battery types necessitated the acquisition of new cases and the new unit is designated Power Source, Model 28110. The decision to change to a battery of different construction was made because the silver-cadmium battery has approximately three times the shelf life of the silver-zinc battery and can be operated at less than one-half the cost per unit time. Additional information about the Model 28110 power source is contained in paragraph 7.6.1.

4.11.5 Thermoelectric Generators

The thermoelectric generators, manufactured by the 3M Company, provide one of the alternate sources of dc power for the portable systems. There were 3 thermopile failures during this report period, of which 2 were replaced under warranty and the third is now being inspected by the 3M Company. Despite these failures, the generators are considered to be a satisfactory alternate power source.

4.12 RECORDING VANS

Five of the recording vans were overhauled during the time they were being held in reserve at the Geotech plant. The repairs that were made are as follows:

a. New tires were installed.

b. The undercarriages were steam cleaned and painted.

c. The van jacks were sand-blasted and painted.

d. The air conditioners were overhauled.

e. Damaged aluminum siding was replaced.

f. The interiors were repainted or refinished.

g. Broken counter tops were replaced.

h. Broken floor tiles were replaced.

i. All wiring was completely checked and replaced as needed.

j. All instrumentation was repaired as needed.

4.13 ANTARCTIC ARRAY SYSTEM

The Antarctic Array instrumentation is a complete seismograph system designed to provide high quality data from a four-element, shallow borehole seismograph array. Consideration of the expected unusually high stray pickup of 60 cps and radio frequency voltages in the 10 kilometer data lines is reflected in the design of this system. This instrumentation will be operated by personnel from Stanford Research Institute (SRI), Menlo Park, California.

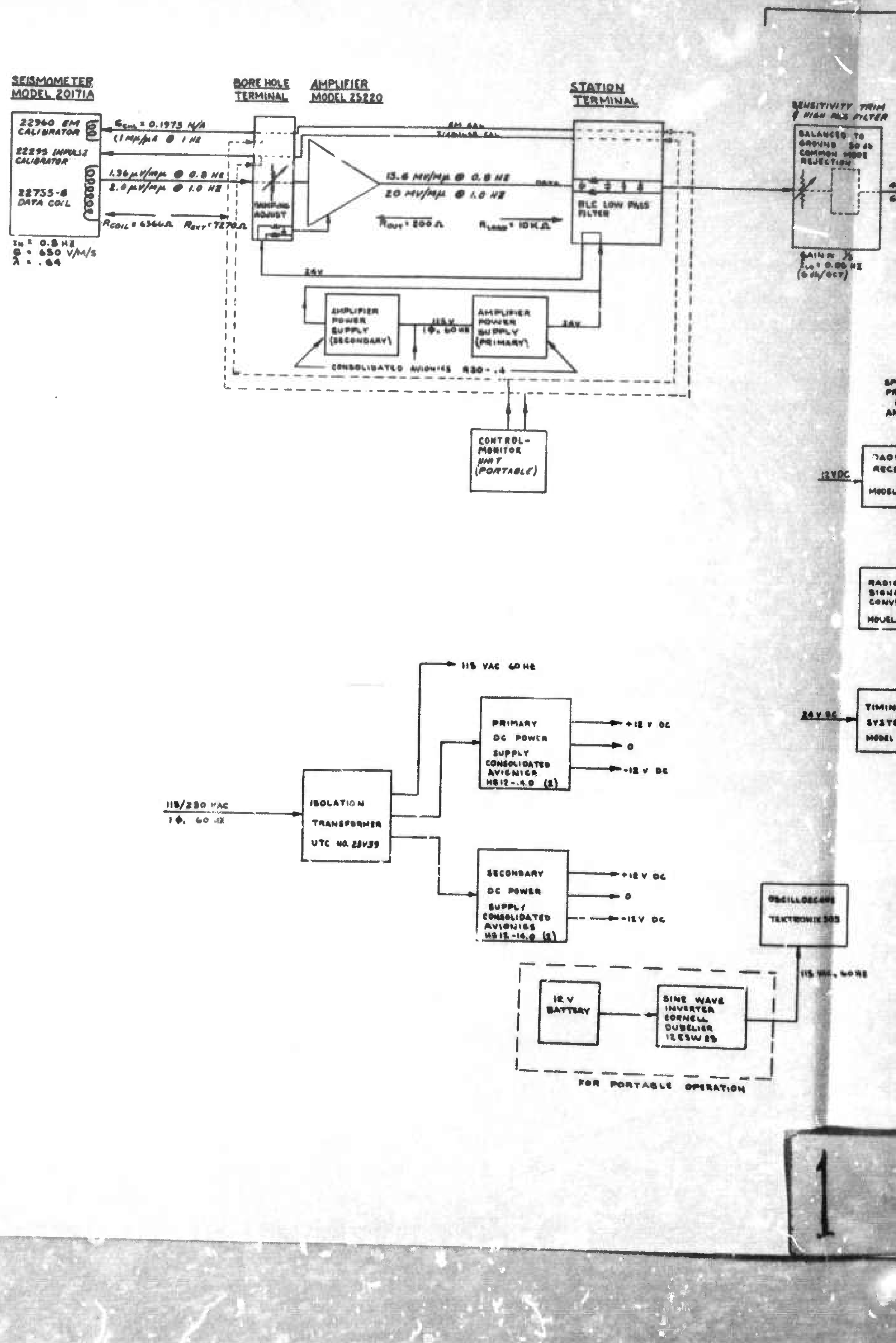
Figure 19 shows a block diagram of the typical channel in the proposed system. Detailed signal and noise voltages and impedance levels are noted on this drawing.

Figure 20 shows the frequency response of a typical channel of the system as it will appear at the input to the recording subsystems. Table 3 is the equipment list.

4.13.1 Borehole Installation

The seismometer used operates at a natural period of 1.25 seconds and a damping factor of 0.64 of critical. The seismometer data lines, calibration lines, and the amplifier input and output cables are terminated at the borehole terminal. The amplifier is suspended down hole on a wire rope.

RF chokes and limiting diodes are installed in the amplifier power circuits at the borehole terminal to reduce the effects of transients and induced noise voltages.


SEISMOMETER MODEL 20171A
22960 EM CALIBRATOR
22295 IMPULSE CALIBRATOR
22755-6 DATA COIL
1.36 μV/mμ @ 0.8 HZ
2.0 μV/mμ @ 1.0 HZ
BORE HOLE TERMINAL
AMPLIFIER MODEL 25220
13.6 MV/Mμ @ 0.8 HZ
20 MV/Mμ @ 1.0 HZ
STATION TERMINAL
RLC LOW PASS FILTER
24V
AMPLIFIER POWER SUPPLY (SECONDARY)
AMPLIFIER POWER SUPPLY (PRIMARY)
CONSOLIDATED AVIONICS R30-.4
CONTROL-MONITOR UNIT (PORTABLE)
SENSITIVITY TRIM & HIGH PASS FILTER
BALANCED TO GROUND 30 db COMMON MODE REJECTION
12VDC
24V DC
115 VAC 60 HZ
PRIMARY DC POWER SUPPLY CONSOLIDATED AVIONICS
+12 V DC
0
-12 V DC
115/230 VAC
1 Φ, 60 HZ
ISOLATION TRANSFORMER UTC NO. 23V39
SECONDARY DC POWER SUPPLY CONSOLIDATED AVIONICS
+12 V DC
0
-12V DC
12 V BATTERY
SINE WAVE INVERTER CORNELL DUBELIER
FOR PORTABLE OPERATION
1

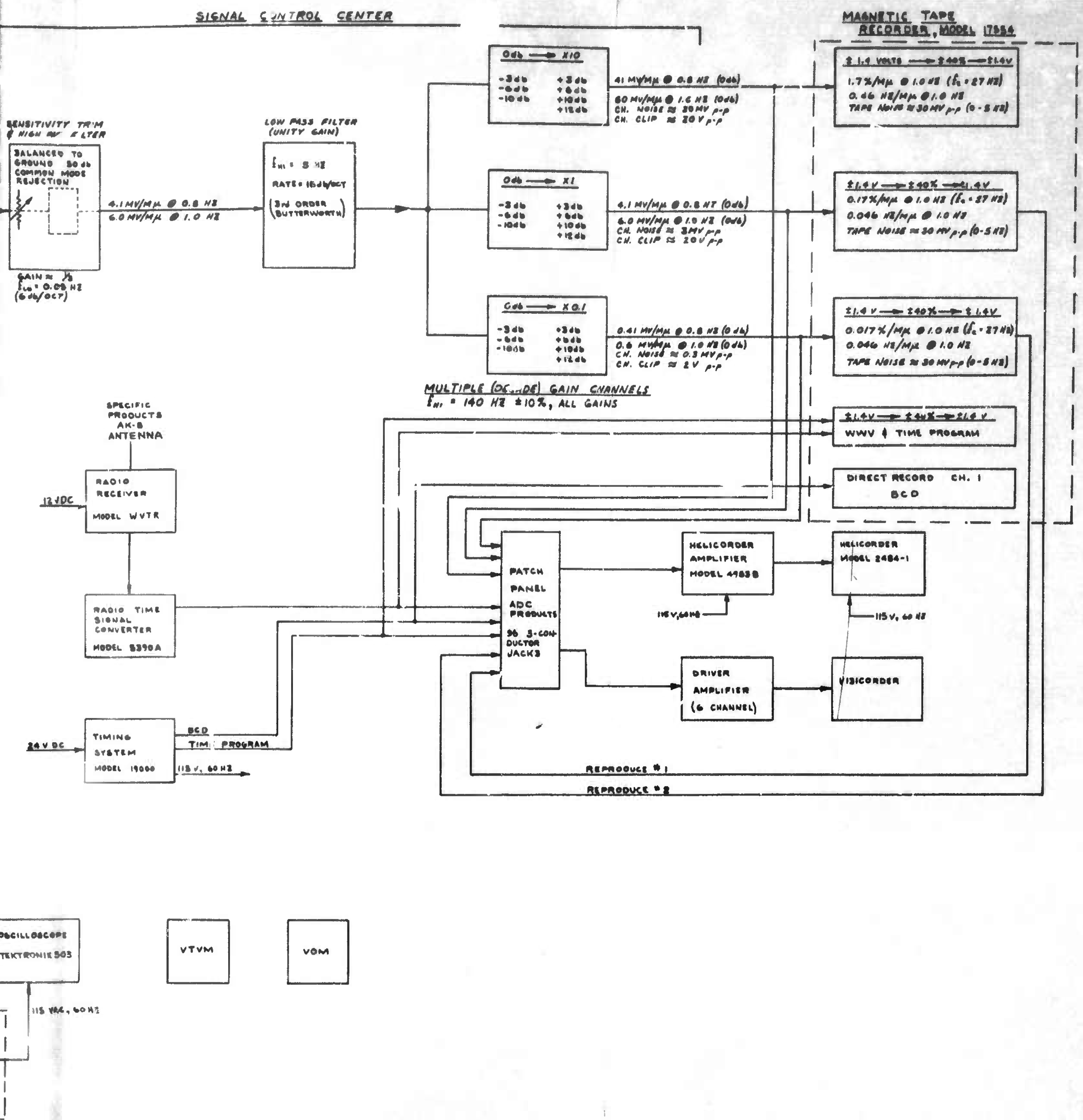


Figure 19. Antarctic array, typical channel

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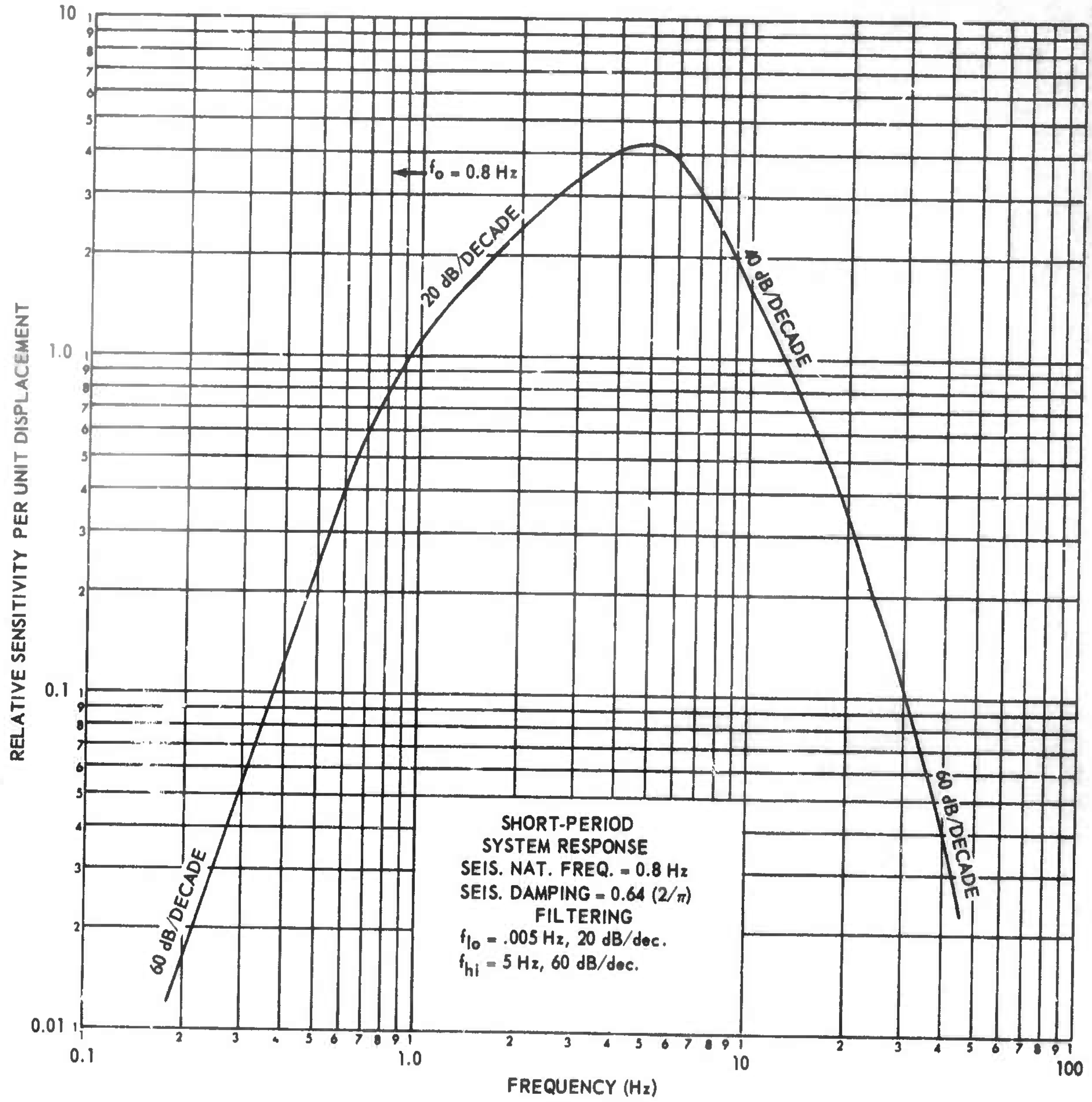

Figure 20. Seismograph frequency response at input to recording subsystem

G 3074

Table 3. Antarctic array equipment list

Item	Description	Type	Quantity
1	Seismometer	20171A	6
2	Amplifiers	25220 (mod)	6
3	Borehole casings	-	12
4	Borehole terminals	-	5
5	Station terminal	-	1
6	Borehole cable	746NT	1300 feet
7	Amplifier power source	R30-.4BF	2
8	Calibration control unit	19823 (mod)	1
9	Signal control center	23403 (mod)	2
10	Patch panel	-	1
11	Helicorder	2484-1	1
12	Helicorder amplifier	4983-B	1
13	Visicorder	-	1
14	Timing system	19000-04	1
15	Radio receiver	WVTR-O	1
16	Radio time signal converter	5390A	1
17	Antenna	AK-8	1
18	Dc power supplies	HS12-14.0	4
19	Dc distribution system	-	1
20	Battery charger	21160	1
21	Isolation transformer and switch box	23V39	1 ea
22	Oscilloscope	503	1
23	VTVM and VOM	-	1 ea
24	Scope chart	-	1
25	Special hand tools	-	1
26	Helicorder paper	-	1 yr supply
27	Magnetic tape	-	62 reels
28	Equipment racks	Honeywell	2
29	Cable splice boxes	-	12
30	Spare parts	-	1 yr supply
31	System operating instructions and wiring diagram	-	
32	Magnetic tape system	17711	1
33	Sine wave inverter	12ESW25	1

A trim on the seismometer damping and signal attenuation at the amplifier input was installed in the borehole terminal.

4.13.2 Data Line Terminal and Signal Control Center

The field cables terminate at the station terminal. Limiting diodes and RF chokes are included in this terminal for each of the four data circuits. A trim on the signal level at the input to the first high-pass filter is installed in the signal control center. This trim is used to match the signal levels from the four boreholes.

The input high-pass filter stage exhibits a common mode rejection of 50 dB or more while attenuating the input signal by a factor of 1/3.

The high-pass filter is followed by a low-pass filter which exhibits the characteristics of a third order Butterworth filter. The low-pass filter has a high cutoff frequency of 5 cps and approaches a cutoff rate of 18 dB/octave. The 5 cps cutoff frequency was selected since it would be required as an "anti-aliasing" filter if the recorded data are to be digitized at a 20-sample per second rate for machine processing.

The total system response as it appears at the input to the various recorders is shown in figure 20. Note that the 20 cps high cutoff frequency in the amplifier affects this response at frequencies above 20 cps and will not necessarily affect the attenuation of 60 cps noise that is induced in the system after the borehole amplifier. This noise is attenuated only by the 40 dB/decade rolloff of the low-pass filter.

4.13.3 Recording Subsystem

A 14-channel (IRIG) magnetic-tape recorder operating at a speed of 0.03 inch per second (ips) is used as the primary data recorder. Data are recorded as a frequency modulated (FM) carrier on tape. The recording VCO carrier frequency is 27 cps.

Three tape channels are used to record each of the three outlying seismometers in the array. The center borehole instrument is recorded on only two tape channels. (Three channels at the signal levels shown in figure 19 are available at the signal control center for all four instruments.)

The tape recorder input circuits are wired directly to the signal control center output circuits and to the system monitor patch panel. A BCD timing channel, time program and WWV radio signal, and a compensation channel take up the remaining tape channels.

The magnetic-tape reproduce electronics is capable of playing back 3 channels of data and 1 channel of BCD time simultaneously.

Two monitor recorders, a Helicorder and a Visicorder, are used to record data in parallel with any of the tape recorder input channels or the playback data from any two of the tape channels. The Helicorder is a single-channel unit. The Visicorder, as provided by SRI, has the capability to record six channels of data.

4.13.4 Timing Subsystem

System timing is provided by a Geotech Model 19000 timing system. This system in conjunction with a radio receiver and antenna system provides a time program, a VELA Standard BCD time code, and 100 watts of frequency-regulated 115-volt power to operate recorder drive motors.

4.13.5 Power Subsystem

All of the seismograph instrumentation is isolated from the primary 115 V, 60 cps power line and the power line neutral by an isolation transformer. This transformer operates on either a 115 V or a 220 V, 60 cps power line.

Two sets of power supplies are provided to furnish the system requirements for ±12 Vdc. Manual switching from one power supply to the other is required.

An additional power supply is provided to supply only the 24 Vdc required by the seismograph amplifiers. The output of this power supply is adjustable over a wide range to provide the required voltage level at the boreholes terminals. Two complete units, again having manual switching capabilities, are provided.

An inverter with sine-wave output suitable to power a Tektronics 503 oscilloscope is provided. The 12 Vdc power source that is required to power this inverter is not supplied. A common truck or motor generator battery will fulfill this requirement.

4.13.6 Calibration

A portable calibration control unit is provided to facilitate the calibration of the seismograph system. This unit has a self-contained battery pack, a function generator, a microammeter, and the controls necessary to perform a complete seismograph calibration. This includes the verification of the absolute magnification, frequency response, and polarity of the seismograph system.

A calibration unit is also provided for aligning and calibrating the tape recorder oscillators.

4.13.7 Test Equipment

A Tektronics 503 oscilloscope is provided for use in maintaining the system. A battery-powered oscilloscope with the capability to make true differential voltage measurements is not available on the market. The 503 oscilloscope was selected because this unit, in conjunction with the sine-wave inverter discussed in paragraph 4.13.5, will provide the capability to operate the oscilloscope in a true differential mode.

A VTVM and a volt-ohmmeter are provided by SRI.

5. EVALUATION OF SUPPORT INSTRUMENTATION

5.1 GENERAL

Support equipment includes instrumentation shelters, vehicles, trailers, and generators. The support equipment discussed in Interim Report No. 3, LRSM Program, remains in use at the field sites. No vehicle replacement or support equipment modifications were implemented during this report period.

5.2 INSTRUMENT SHELTERS

The instrumentation shelters used in the LRSM program have remained unchanged during this report period. The instrumentation vans, phototube amplifier shelters, and seismometer vaults of the mobile observatories have continued to provide satisfactory protection for our instrumentation. The shelters used in portable system operations have also been adequate for our requirements.

5.3 VEHICLES

The vehicles used by the LRSM teams during this report period were as follows:

a. Heavy-duty personnel carriers and pickup trucks used to transport personnel and equipment to and from field sites;

b. Heavy-duty trucks used for transporting the mobile observatories during station moves;

c. Special purpose vehicles used when the normally assigned vehicles are inadequate for the task;

d. Utility trailers used for transporting generators and equipment in the field.

During this report period the LRSM vehicles were driven approximately 522,000 miles and only seven accidents were recorded. One of these accidents caused a team member to be hospitalized because of injuries.

Early in 1967, six 3/4-ton heavy-duty Chevrolet pickup trucks were ordered under a lease contract for the portable system teams. These trucks will be equipped with enclosures mounted over the pickup bed and will have a capacity to carry all of a team's equipment. Delivery is expected about 1 June 1967. These new trucks will replace the six heavy-duty personnel carriers that are now assigned to the portable teams.

5.3.1 Heavy-Duty Personnel Carrier

At the close of this report period, 12 of the original 40 personnel carriers remained in service in the LRSM program. These vehicles have been driven an average of 84,000 miles each. They have been in constant service during the past 6 years and have provided adequate transportation for the field teams;

however, the operation and maintenance costs of these vehicles are becoming excessive as their mileage increases. At present, only three of these units are in daily operation.

5.3.2 Heavy-Duty 3/4-Ton Pickup Trucks

At the end of May 1967, 15 of the original 40 pickup trucks remained active in the LRSM program. The average mileage for each of these units was 56,000. The greatest part of this mileage has been accumulated on unimproved roads. This type of driving subjects these vehicles to a great deal of abuse from vibration and damage from gravel thrown by passing vehicles. The remaining mileage has generally been accumulated towing the instrumentation vans during team moves. The average operational cost for these vehicles during this report period has been 21 cents per mile.

5.3.3 Heavy-Duty 1/2-Ton Pickup Trucks

Ten heavy-duty 1/2-ton pickup trucks were acquired in August 1965 on a lease agreement. These units were obtained to replace those personnel carriers that, because of their high mileage, had become unreliable or uneconomical to maintain. On 31 May 1967, the average number of miles per pickup truck was 37,200 - a large part of this mileage being accumulated on unpaved roads. These units have provided personnel transportation at low operating costs.

5.3.4 Two and One-Half Ton Truck

The numerous failures of the 3/4-ton heavy-duty pickups while towing instrumentation vans indicated that a more suitable vehicle was needed to furnish a reliable means of transporting the vans over long distances. In October 1964, a 2-1/2 ton truck was leased to fulfill this requirement. This unit is dispatched from Garland when a van move is to be undertaken and is not used for personnel transportation. This vehicle has been driven over 58,500 miles with few mechanical breakdowns. The only serious failure occurred while the unit was still under warranty. An oil pump failure necessitated an engine replacement. The operational cost for this unit is approximately 30 cents per mile, but the greater degree of personnel safety and the decrease in travel time during team moves justify this cost. The use of this vehicle was so successful that a second unit was leased in March 1966. During this report period, each of these vehicles was driven approximately 12,000 miles.

5.3.5 Kristi Snow Vehicle, Model KT-3

A Kristi Snow Vehicle, Model KT-3, was purchased in October 1962. Since that time it has been assigned to several teams located in areas of severe weather conditions. During this report period, it has been used by the team operating in Schefferville, Quebec, Canada (SV3QB). The use of this vehicle is restricted to times when other team vehicles cannot operate due to heavy snow accumulation.

The SV3QB team used this vehicle a total of 30 hours during the winter of 1966-1967.

5.3.6 Utility Trailers

The 13 utility trailers currently in use in the LRSM program are used to transport generators and instrumentation in the field. These units have been used extensively during portable system operations. During Project EARLY RISE the portable teams installed all equipment on wooden platforms mounted inside these trailers. This provided easy access to equipment during operation and reduced set-up and pick-up time. The operational cost for the utility trailers has been low, with the major expenses being incurred for licensing and tires.

5.4 GENERATORS

At the close of this report period, 19 U. S. Motors and 1 PE-95, 15-KVA generators were available for use at site locations where commercial power could not be economically obtained. Four of the U. S. Motors' generators are in service at field locations and the remaining 15 units are being maintained at the Garland plant. The generators have performed satisfactorily under many different climatic conditions. However, as the number of operating hours increases, repairs become more frequent and operational costs are correspondingly increased. Several of the units located in Garland are maintained in an operationally ready status and can be sent to the field on short notice.

In addition to the twenty 15-KVA generators, three Caterpillar 30-KVA diesel generators were in use during this report period. At present, two of the units are being operated at sites as the primary power source, and a third unit is used as a standby generator at the NP-NT site. These generators have provided reliable service for extended periods of time.

A summary of the field teams which were operating on generator power on 31 May 1967 is given below:

Team	Type of generator
KN-UT	Caterpillar - primary U. S. Motors - standby PE-95 - standby
RK-ON	Caterpillar - primary U. S. Motors - standby
PG-BC	U. S. Motors - primary U. S. Motors - standby
NP-NT	Caterpillar - standby

6. EVALUATION OF SEISMOGRAMS

6.1 INTRODUCTION

The professional quality of LRSM seismograms and supporting data, continues to be closely checked by two support groups within the Data Reduction section. The Data Control group examines 35 mm and 16 mm film records and associated logs, while the Special Presentations group is responsible for the critique of magnetic-tape recordings and magnetic-tape operations logs. Critique check lists and the LRSM Field Operations Manual, which establish the operational tolerances, are the guides used by each group during a critique. During the period covered by this report, the Data Control group made several modifications to existing quality control procedures and/or field team operational techniques. These are reviewed in the paragraphs which follow.

6.2 FILM QUALITY CONTROL

Several special studies aimed at improving data or simplifying operational procedures were conducted during the report period. The primary responsibility of the Data Control group, however, continues to be the evaluation of all film data and supporting operations logs produced by the field teams. The fundamental purpose of the critique is to maintain the professional quality of data by a system of periodic checks and written descriptions of the results of the critique. Of secondary importance, the critique provides useful information on equipment failure trends, team operator efficiency, validity of established operational tolerances, changes in seismic background levels, etc.

6.2.1 Procedural Modifications

During this report period, the group has closely surveyed the procedures, tolerances, point values, and forms used during a critique in light of staying current with changing capabilities and objectives. As a result of these examinations, three modifications were made to the quality critique procedures.

a. Critique point value revision. To further stress the importance of accurate, well recorded data, the critique point values were revised on 1 January 1967 to place more emphasis on those errors or omissions which directly affect the credibility of the data. The fundamental change in this revision was that of deducting points for principal problems on a "per occurrence" basis rather than "per critique."

b. Critique statement changes. Experience has shown that some few standard critique statements can become ambiguous or out-dated with time. The Data Control group routinely reviews these statements and initiates changes when they are deemed necessary. Several critique statements were changed or deleted during the past 14 months.

c. Monthly critique summaries. As a result of an evaluation of monthly critiques during this report period, the following changes will be made effective 1 June 1967. The Data Control group will review one set of film from all teams each week, thereby doubling the number of critiques heretofore conducted.

The critique summary for the month will indicate the number of times any one deficiency was noted during a month, and this figure can be used in judging the importance of the deficiency. An example of the new format is shown in figure 21.

At any time during a month when a condition at a site is observed which is affecting the quality and reliability of the data, and which can be corrected by the field team, the critique analysts will send an informal memo to the Field Supervisor, setting forth the details of the problem. In this manner, problems which require attention can be acted upon quickly.

6.2.2 Field Operations Modifications

Based on the recommendation of a Field Team Supervisor, members of the Data Control group conducted an experiment aimed at reducing the number and severity of scratches on 35 mm film seismograms.

The study tested a simple but effective method of eliminating film emulsion damage while the seismograms are being drawn through any viewer or projector. Two strips of undeveloped film, with the emulsion removed, were used as a protective "sandwich" around film seismograms and were drawn through viewers which were known to scratch film emulsion. The seismograms sustained virtually no damage even after repeated tests of careless handling.

This technique for film handling was introduced to all LRSM teams near the end of this report period. It is expected that during the coming months, film emulsion damage will cease to be a problem.

6.3 MAGNETIC-TAPE QUALITY CONTROL

Magnetic-tape records from each site are selected for review on a random basis. Each tape seismogram is evaluated primarily on signal and calibration levels, system alignment, and timing accuracy; operations logs are checked for completeness, accuracy, and neatness.

The Special Presentations group continues to use the present quality control grading system. Grading under this system is on a point credit basis; that is, points are given for each correct performance. When any deficiency occurs, points will not be credited. Figure 22 is a copy of the tape recording Critique Check List. There are 250 points total on the list. After a critique is complete, grades will be determined by dividing the points earned by 250. For example, a point total of 200 represents 80 percent of 250; accordingly, the grade will be 80.

The points are distributed throughout the various categories on the check list to emphasize those areas which require the greatest effort to assure the recording of high-quality data. Table 4 is a composite of the results of the critiques conducted during April 1967. A similar review is printed monthly.

During the previous 14 months, 250 magnetic-tape recordings have been reviewed and evaluated by quality control technicians. Listed below are the problems most frequently encountered by field teams as detected and analyzed by these technicians.

35 MM FIELD SITE RECORD CRITIQUE

FIELD SITE HN ME
TEAM NO. 30

PROJ. MGR. R.G. REAKES
SUPERVISOR ALLPORT

CRITIQUED BY L. R. JOHNSON
CUMULATIVE AVG. 80

DATES OF FILM CRITIQUED
08, 14, 22, 27 JULY 1967

GRADE 86
****

1. RECORD SHIPMENT
   1.1 PROMPTNESS
   1.2 PACKAGING

2. LOGS AND FILM WRAPPER
   2.1 NEATNESS
   2.2 COMPLETENESS
   2.3 ACCURATE MEASUREMENTS -060
   2.4 ACCURATE COMPUTATIONS

3. FILM QUALITY
   3.1 PHOTOGRAPHY -062
   3.2 HANDLING -048

4. DATA QUALITY
   4.1 OPERATIONAL SCH. -006
   4.2 OPERATIONAL TOL. -080
   4.3 STATION TIME
   4.4 WWV RECEPTION
   4.5 IRREGULARITIES -285

QUALITY CONTROL REMARKS

2.3.A.1.	QC DIFFERS MORE THAN 2MM ON THE MEASURMENT OF -- SPR BL CAL (1),LPZ (1),LPR (1)	03
3.1.A.1.	THE FILM IS OUT OF FOCUS ON THE END -- SPR (3)	01
3.1.B.5.	THE TEN SECOND MARKS ARE NOT VISIBLE ON -- LPZ (1),LPR (1)	02
3.1.E.6.	THERE ARE CHEMICAL STAINS ON -- SPZ(1,2,3,4),SPR (3),SPT (3),LPZ (1,2,3,4),LPT (1,3) LPZ-LO (3)	13
3.1.F.	THERE IS EXCESSIVE RESIDUE ON -- RADIO (2),SPZ (2),LPZ (2)	03
3.2.A.1.	THE SCRIBING IS IN ERROR ON -- SPZ G (3)	01
3.2.B.1.	THERE ARE EXCESSIVE SCRATCHES ON -- RADIO (2),SPZ (1),LPZ (1),LPZ-LO (1)	04
3.2.B.4.	THERE IS EMULISION DAMAGE ON -- LPT (3)	01
4.1.B.1.	THERE IS OUTAGE ON -- LPT 2213Z - 2315Z (3)	01
4.2.B.	THE DAMPING RATIO IS OUT OF TOLERANCE -- SPT (3)	01
4.2.H.	THE MOTOR CONSTANT IS OUT OF TOLERANCE -- SPR (1,4)	02
4.2.1.3.	THIS CALIBRATION WENT OFF THE FILM -- SPT (2),LPR (2)	01

Figure 21. 35 mm field site record critique

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4.5.B.1.   THERE IS CROSSTALK ON --
             SPZ (1,2),SPR (1,2),SPT (1,2)                                        03
4.5.C.2.   THERE IS TRACE DRIFT ON --
             LPT (2)                                                              01
4.5.D.1.   THERE ARE SPIKES ON THE WEIGHT OFF BALL LIFTS --
             SPZ (1,2),SPR (1,2),SPT (1,2)                                        03
4.5.D.3.   THERE ARE SPIKES ON --
             SPZ (1),SPR (1),SPT (1,2)                                            04
4.5.F.1.   THERE ARE TRACE OFFSETS ON --
             RADIO (3),LPR (1),LPT (2)                                            03
4.5.G.3.   THE FOLLOWING CALIBRATIONS ARE NOT RELIABLE --
             LPR (2)  See 4.2.1.3                                                 01


GRADE SUMMARY FOR ALL SITES

    MONTHLY GRADE RANGE                          YEARLY CUMULATIVE AVG.
        HIGH 93                                      HIGH 91
        LOW  75                                      LOW  77
        AVG. 85                                      AVG. 83
```

Figure 21. 35 mm field site record critique, Continued

Field Site ____________ Team Number ____________

Run Number ____________ Team Supervisor ____________

		CREDIT POINTS	FIELD MANUAL REFERENCE
1. RECORD SHIPMENT			
1.1 Promptness	5	Prompt shipment of tape and tape system logs	Sec I:6.2
1.2 Label	5	Properly filled out data label	Sec I:5.4.2
1.3 Stamp	5	Neat, correctly placed I.D. stamp on tape box	Sec I:5.4.3

2. LOGS

2.1 Completeness

Magnetic-tape log remarks are of extreme importance for advising data processing personnel of all conditions that existed during a recording period. Tape Q.C. will require that remarks be entered to explain any conditions affecting the data recorded. For example, when weather conditions are a factor affecting recorded data these conditions, and the times of any changes, must be described. Consideration will be given where it is reasonable to assume that team personnel could not be aware of unusual conditions. Credit for completeness will be given under the appropriate category being critiqued (Sec I: 4.6.1).

2.2 Neatness	5	General tape system log neatness	Sec I: 4.1
2.3 Accuracy			
2.3.1 Measurements	10	Accuracy of measurements entered on tape system log. ± 2%	
2.3.2 Computations	10	Accuracy or computations entered on tape system log. ± 2%	

Figure 22. Magnetic-tape critique check list

	CREDIT POINTS		FIELD MANUAL REFERENCE
3. TAPE SYSTEM			
3.1 Tape Speed	5	Maintaining tape transport speed within tolerance (±0.5%) after receipt of notice from Q.C. of an existing tape speed error	
3.2 Tape System Noise (50 cps filter)	20	Maintaining a tape system noise level of 60 mV or less	
	10	Bonus points for noise level consistently meeting specs from critique to critique	
4. MAGNETIC TAPE RECORD			
4.1 Markings	10	Properly marking each tape with team stamp, start time, and first 5-minute mark	Sec. I: 5.4.1
4.2 Leader	5	Taking up 15 turns of tape on takeup reel before starting each day's run	Sec. II: 5.3.4
4.3 Voice Comments	20	Clear, understandable voice comments. Throughout each run	Sec. II: 5.3.5
4.4 Calibration Times	10	Performing calibrations at specified times	Sec. I:2.1.1
4.5 Polarities	5	Maintaining proper polarities	Sec. II: 3
4.6 Channel Priority	10	Following specified channel priority	Sec. II: 5.2
4.7 Tape Alignment	20	Accurately performing the tape system alignment	Sec. II: 5.3.1

Figure 22. Magnetic-tape critique check list, Continued

	CREDIT POINTS	FIELD MANUAL REFERENCE
4.8 Record Change	10 Proper time of record change	Sec. II: 5.3.4
4.9 WWV	10 Maintaining correct WWV record level during periods of good radio reception	Sec. II: 5.4.3
4.10 Station Time	15 Maintaining correct record level and high-to-low level ratio of 60 cps timing signal on channel #14	Sec. II: 5.3.1
5. DATA		
5.1	20 Maintaining dc offsets within tolerance. Tape system ±40 mV; PTA ±30 mV	Sec. II: 4.5.2
5.2	15 Maintaining proper signal background levels. SP - 60 mV LP - 100 mV ±50 mV	Sec. II: 5.4.2
5.3	25 Maintaining calibrations at specified levels. SP - 2.0 to 2.5 V p-p LP - 0.5 to 2.5 V p-p (measured at 1.0 cps for SP and 0.04 cps for LP)	Sec. I: 2.3.2

Figure 22. Magnetic-tape critique check list, Continued

Table 4. Field tape review No. 55, April 1967, summary

Team No.	Desig-nator	Tape dates	Logs	WWV Ratio	WWV Level	Voice comments Ratio	Voice comments Level	Station time Ratio	Station time Level	Tape system noise (mV)	Background levels SP	Background levels LP	D.C. Offsets channel No.	Calibration levels SP	Calibration levels LP	Remarks	Grade
13	HP-NT	21 March 67	Incomplete	OK	OK	OK	OK	OK	OK	OK 40 mV	OK	OK	OK	OK	OK	Weather conditions not noted on log	98
3	RK-ON	5 April 67	Incomplete	OK	OK	OK	OK	OK	OK	OK 50 mV	OK	OK	OK	OK	OK	Weather conditions not noted on log	98
28	PG-BC	5 April 67	OK	Poor	Poor (R)	OK	OK	OK	OK	OK 45 mV	OK	OK	OK	OK	OK	Starting dc offsets on border line of tolerance	92
35	MN-NV	5 April 67	OK	OK	OK	OK	OK	OK	OK	OK 50 mV	OK	OK	13	OK	OK	Channel 13 ending dc offsets out of tolerance	92
11	KN-UT	5 April 67	Neatness	OK	OK	OK	OK	OK	OK	OK 40 mV	OK	OK	13	OK	OK	LPZ on log reads 1198, should read 1.98	88
8	5V3QB	5 April 67	Incomplete	OK	OK	OK	OK	OK	OK	OK 35 mV	OK	OK	5,9,13	OK	OK	Calibrations were performed at other than specified time	86
27	WH2YK	5 April 67	Incomplete	OK	OK	Poor	OK	OK	OK	OK 40 mV	OK	OK	11,13	OK	OK	LPR and LPZ cal's drifting	82
30	HN-ME	5 April 67	Incorrect	OK	OK	OK	Poor	OK	OK	OK 50 mV	OK	OK	11,12	OK	OK	Measurements entered on log incorrect	80
33	MO-IO	19 April 67	Incorrect	OK	OK	OK	OK	CX	OK	OK 50 mV	Hi-All	Hi-All	2,4,5,8,9,11	OK	Z-Hi	"Y" calculations for LPZ, LPR, are incorrect	64
36	FK-CO	5 April 67	Incorrect	OK	Poor	Poor (R)	OK	OK	OK	OK 45 mV	OK	OK	OK	OK	OK	Cal levels not readable on channels 4, 11, 13	64
-	LZ-BV	28 Dec 67	OK	Poor	Poor	Poor	OK	OK	OK	OK 50 mV	OK	OK	1,12	OK	OK	5 Channels inoperative	
	PORTABLE SYSTEMS																
52	IC-GL	9-13 April 67	OK	OK	OK	OK	OK	OK	OK	OK 50 mV	OK	OK	OK	OK	OK	Tape speed 4.1 sec fast in 10 min check	100
50	SA2TX	21-28 April 67	OK	OK	OK	OK	OK	OK	OK	OK 40 mV	OK	OK	OK	OK	OK	Tape speed 2 sec fast in 10 min check	100
51	ST1TX	15-21 April 67	OK	OK	OK	OK	OK	OK	OK	OK 30 mV	OK	OK	1,3,5,8	OK	OK	Periods of high background noise	92
53	ST2TX	16-21 April 67	OK	OK	OK	OK	OK	OK	OK	OK 30 mV	OK	OK	3,5,8	OK	OK	Excessive dc offsets, channels 3, 5, 8	92
54	ST4TX	16-21 April 67	OK	OK	OK	OK	OK	OK	OK	OK 30 mV	OK	OK	3,8	OK	OK	Ball lifts and dc pulses not readable	92
55	SA4TX	17-21 April 67	OK	OK	OK	OK	OK	OK	OK	OK 40 mV	OK	OK	OK	Z,R,T,Lo	OK	Calibration levels on channels 3, 5, 8, out of tolerance	82
																(R) Denotes repeat critique	
																Average Grade	87.6
		SPECIFICATIONS:	Neat Correct Complete	Good Quality Proper Level		Good Quality Proper Level		3/1 Ratio Proper Level		<60 mV	SP 60 mV ±25 Array 100 mV ±30 DW 100 mV ±30 PS 100 mV ±30 LP 100 mV ±30		Tape ±40 mV PTA ±30 mV	SP Arr 2.0/2.5 PS Dw V p-p LP 0.5/2.0 V p-p			
			1 Not Neat 3 Incorrect 4 Incomplete	2 Poor Quality 3 Poor Level		3 Poor Quality 1 Poor Level		OK		OK	1 Team High		10 Teams had dc offsets	3 SP Lo 1 LP Hi			

a. Station time. All operational teams encountered some form of difficulty with recording station timing. Most problems have been determined to result from oxide buildup on the record heads, resulting in partial or total loss of data.

b. Seismic background levels. All operational teams recorded seismic background levels in the SP frequency spectrum either below or above specified levels, and all teams recorded LP background levels either above or below tolerance limits. Weather and other atmospheric conditions have accounted for 75 percent of these difficulties.

c. Dc offsets. The primary contributors to the dc offset problems encountered by field teams have been unstable weather conditions which caused unbalance and drift in the phototube amplifiers. The drift is produced both by the galvanometer suspensions and the mechanical linkages in these units.

d. Tape system noise. Tape system noise has been a problem to all field teams. Only 0.1 percent of these noise problems has resulted in rendering the seismic data unusable. The primary cause of the tape system noise is faulty tape transport bearings.

6.4 QUALITY ASSURANCE

On 1 April 1966, a Quality Assurance (QA) task was established within the LRSM program. The function of QA was to stimulate interest in and develop a broad-based program of orientation - embracing data analysis, administration, and a review of instrumentation and operational procedures.

In partial fulfillment of this task, the Data Control group was asked to carefully review the results of their critiques to detect patterns of lower-than-average results at any site in film processing or in interpreting directives in the Field Manual. If, after a thorough analysis of all pertinent factors, it was determined that a visit to a site was advisable to correct deficiencies, the QA representative would plan for such a trip in the company of the team's supervisor. The planning for these trips covered three primary objectives:

a. To correct, by personal instruction, the observed deficiencies in the data handling techniques;

b. To observe all phases of data handling and provide instruction on implementing new or better techniques. This phase of the trip included a detailed review of the current studies being performed with the data; the importance of high-quality data to support these studies, and the role of the team member in relation to practical and theoretical studies which use LRSM data;

c. With the team's supervisor, review all aspects of the team's data acquisition efforts, including technical, operational, and administrative procedures.

Five teams were visited under the QA plan described above. These sites were FK-CO, MO-ID, KN-UT, MN-NV, and HN-ME.

Other tasks which have been accomplished under QA during the past 14 months include:

a. An orientation program of 2 weeks' duration for the team members of the vans deactivated during January 1967:

b. Mailings to the field teams of data processing and analysis information, and of reports written under LRSM;

c. Preliminary investigation into a program whereby current Telephone Status Reports would be compared to the results of an analysis of the film data by a qualified analyst. When discrepancies occur, QA would reproduce the data segment and prepare an analysis summary of the event. These would be returned to the team to serve as an aid in observing and timing future events. This program will be initiated during July 1967.

The QA task has complemented the efforts of the Quality Control group by providing field-oriented programs geared to improve data quality.

6.5 INTERIM LRSM LIBRARY

The Interim Library continues to perform the following support services to LRSM:

a. Receive data from the field teams. Establish accountability for and store this data to ensure against its loss and to provide for easy access by data users.

b. Review operations logs and film wrappers and monitor team shipping schedules. Notify Quality Control when deficiencies occur.

c. Make monthly data shipments to the Seismic Data Laboratory (SDL) in Alexandria, Virginia.

d. Prepare and ship film and magnetic-tape copies in response to data requests approved by the Project Officer.

e. Coordinate the processing, accountability and shipping of the magnetic tape and 35 mm film playouts of portable systems data.

In addition to these activities, library personnel provided the bulk of the planning and organization of the Electronic Data Processing (EDP) operations log concept (described in the following paragraph).

6.6 EDP LOG FORMATS

During 1966-67, a new format for the LRSM operations logs was developed and tested at several field teams. This format takes advantage of EDP techniques to perform certain calculations and print the logs from simplified work sheets, which can be quickly filled in by the station operators. Approval of this format has been received from the Project Officer and plans have been formulated to initiate the use of these logs on 1 August 1967.

The most striking change in the format of the new log program is the EDP card-type layout of the work sheets to be completed by the field team operators. Completion of these work sheets requires only entering numbers in appropriate blocks each day. The work sheets will be completed on a weekly rather than daily basis and no data are repetitive from sheet to sheet. An example of a properly completed SP system work sheet is shown in figure 23.

The work sheets will accompany each data shipment to the LRSM library where they will be reviewed for completeness and assembled for transferring the data to punched cards. The program which converts the cards to operations logs provides the flexibility required for all foreseeable changes in LRSM requirements. Only one log will be produced for each team daily. It is designed to contain all the variables and most of the constants that are on the present logs. The frequency response page of the currently used SP and LP logs will be completed when scheduled and forwarded with the work sheets. These curves will be attached to the applicable EDP log after it has been processed.

Several studies are scheduled to be conducted during the coming contract period which heretofore could not be initiated because of the difficulty in manually extracting data from the operations logs.

6.7 TELEPHONE STATUS REPORTS

The Telephone Status Report is a single page summary of a special event which lists the operational status of each field team at the time of the event, the distance of each station from the event and an indication of whether or not a signal was recorded at each station. The report serves the Project Officer as a preliminary indicator of the results of a special event and its value is based on the speed with which it is distributed.

In April 1967, the Data Control group accepted full responsibility for the preparation and distribution of these reports. Since this time, all telephone status reports have been distributed within 8 working hours of an event occurrence.

7. EQUIPMENT MODIFICATIONS

7.1 GENERAL

This section describes the modifications performed on the LRSM instrumentation to improve system reliability.

7.2 LIGHTNING PROTECTION

Gas diode lightning protection systems have been incorporated into 7 of the LRSM van systems and 5 portable systems. Protection was provided on all field circuits at the seismometers and at the recording equipment location. Figure 24 shows the prototype of the portable system station protector.

CARD FORMAT LRSM SHORT - PERIOD LOGS

STATION			YEAR		MONTH	
1	2	3	4	5	6	7
P	G	-	6	7	0	8

STATUS AND WEATHER CODES

CALIBRATION CODES (COL. 10, 20, 30)

- B - BALL LIFT CALIBRATION GAINS
- M - MANUAL WEIGHT LIFT GAINS
- S - SINE WAVE GAINS AT 1 CPS
- D - DC PULSE GAINS
- I - INOPERATIVE INSTRUMENT
- N - NO REQUIREMENT
- E - EXPERIMENTAL

OUTAGE TIME REASON (COL. 78-79)

- XM - MOVING
- XS - SETTING UP
- EM - EQUIPMENT MOD.
- SF - SYSTEM FAILURE
- XN - NO REQUIREMENTS
- OE - OPERATOR ERROR
- PM - PREVENTIVE MAINT.
- GF - GENERATOR FAILURE
- PF - COMMERCIAL POWER FAILURE
- AG - ASSIGNED GAINS
- OR - OTHER REASONS
- XC - OTHER CALIBRATIONS
- XW - WEEKLY CALIBRATIONS
- XE - ECM CALIBRATIONS

WEATHER CODES

CLOUD COVER (COL. 73)

- N - NONE
- P - PARTLY CLOUDY
- C - CLOUDY

PRECIPITATION

TYPE (COL. 74)

- R - RAIN
- S - SNOW
- H - HAIL
- I - ICE, SLEET

MEASUREMENT (COL. 75)

- T - TRACE
- I - INCHES
- F - FEET

	VERTICAL				HORIZONTAL SPR				HORIZONTAL SPT			
DAY	CAL CODE	DAMPING RATIO	GAIN K	"G" IN NEWTONS PER AMP	CAL. CODE	DAMPING RATIO	GAIN K	"G"	CAL. CODE	DAMPING RATIO	GAIN K	"G"
8-9	10	11-13	14-16	17-19	20	21-23	24-26	27-29	30	31-33	34-36	37-39
01	B	144	206	415	B	150	198	396	B	163	210	401
02		151	207	416		146				164	211	399

DAY	OUTAGE TIME SPZ FROM	SPZ TO	SPR FROM	SPR TO	SPT FROM	SPT TO	TEMPERATURE + –	MAXIMUM	+ –	MINIMUM	WIND VELOCITY MAXIMUM	DIRECTION	MINIMUM	DIRECTION	CLOUD COVER	PRECIP TYPE	T I F	AMOUNT	STATUS CODE	SYSTEM CODE
8-9	40-42	43-45	46-48	49-51	52-54	55-57	58	59-61	62	63-64	65-66	67-68	69-70	71-72	73	74	75	76-77	78-79	80
01	005	007	005	005	005	007	+	067	+	42	15	SW	00		N			00	PM	1
02								071		38	5	E								1
																				1
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FORM 394 (REV. 7-67)

Figure 23. Short-period system work sheet

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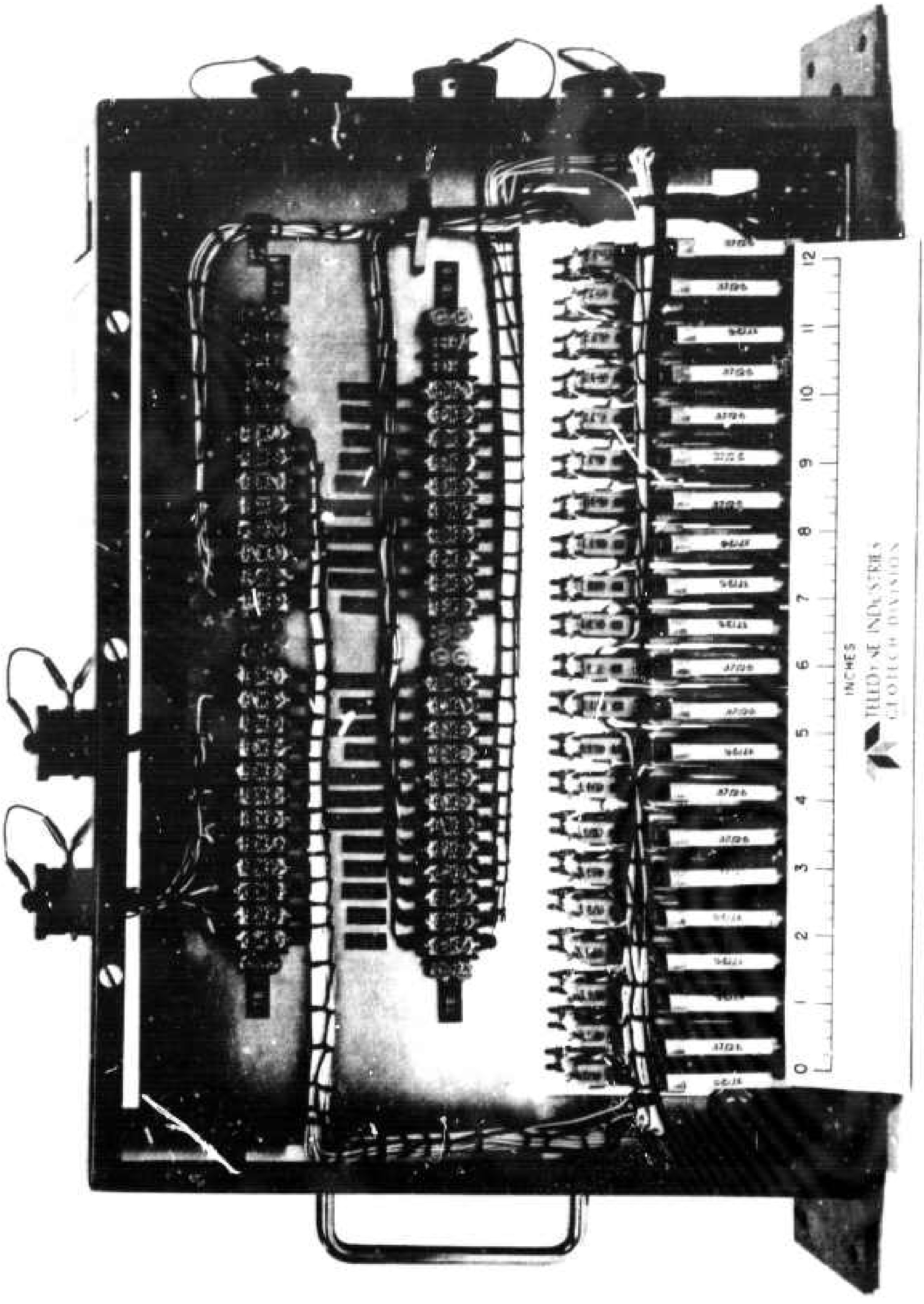


G 3076

Figure 24. Portable system station protector

7.3 RECORDERS

7.3.1 Magnetic Tape

The fluid in the viscous tape supply units on the Ampex Magnetic-Tape Recorder, Model 314, was replaced with fluid of 12,500 centistoke viscosity (cs). Comparison tests were performed on 10,000 cs, and 12,500 cs Dow Corning D. C. 200 silicone fluid to determine their operating characteristics.

The results of the tests are shown in figure 25. The range of the tension provided by the 10,000 cs fluid was from 2.375 oz at the beginning of the tape reel to 6.810 oz at the end. The 12,500 cs fluid provided from 3.311 oz to 11.311 oz tension. The recommended tension for the tape supply is 8.0 oz.

7.3.2 Helicorder, Model 12400

The pen heat circuit in the portable system Helicorder was redesigned and component changes were made in the circuit. This circuit is shown in figure 26. The transistors now used are matched pairs. Resistor R407 was changed from 1 W to a 10 W power resistor. This redesign is expected to provide better current regulation and increase the stability and reliability of the pen heat circuit.

7.4 AMPLIFIERS

Ceramic stops were installed in the LP phototube amplifier galvanometers. The ceramic stops insulate the coil form from static charges on the galvanometer barrel. This prevents the coil from sticking against the limit stops.

7.5 TIMING SYSTEMS

The Timing Systems, Model 5400, in the LRSM vans were replaced with Timing Systems, Model 19000. The Model 19000 is a solid-state timing system employing a crystal oscillator with a drift rate of 1 part in 10^9 per day as the primary frequency standard. The unit generates a SP and a LP program, an automatic ball-lift program, and VELA-Uniform binary coded decimal time. The secondary frequency standard is a 960 cps tuning fork oscillator. The unit includes a power amplifier with a 100 VA, 60 cps frequency-regulated square-wave output. Figure 27 shows this unit in its rack mount configuration.

Intermittent count problems encountered after the initial installation of the Model 19000 timing systems were solved by modifying the inverter gate circuit. This modification consisted of removing two capacitors and changing the value of another capacitor on the inverter gate printed circuit board.

The Timer-Programmer, Model 19754, for the engineering model of the portable seismograph system (designated as Team 50) was updated and modified to make it compatible with the other portable systems. The timing system was changed to the Model 19000-M1 configuration and a new carrying case was obtained.

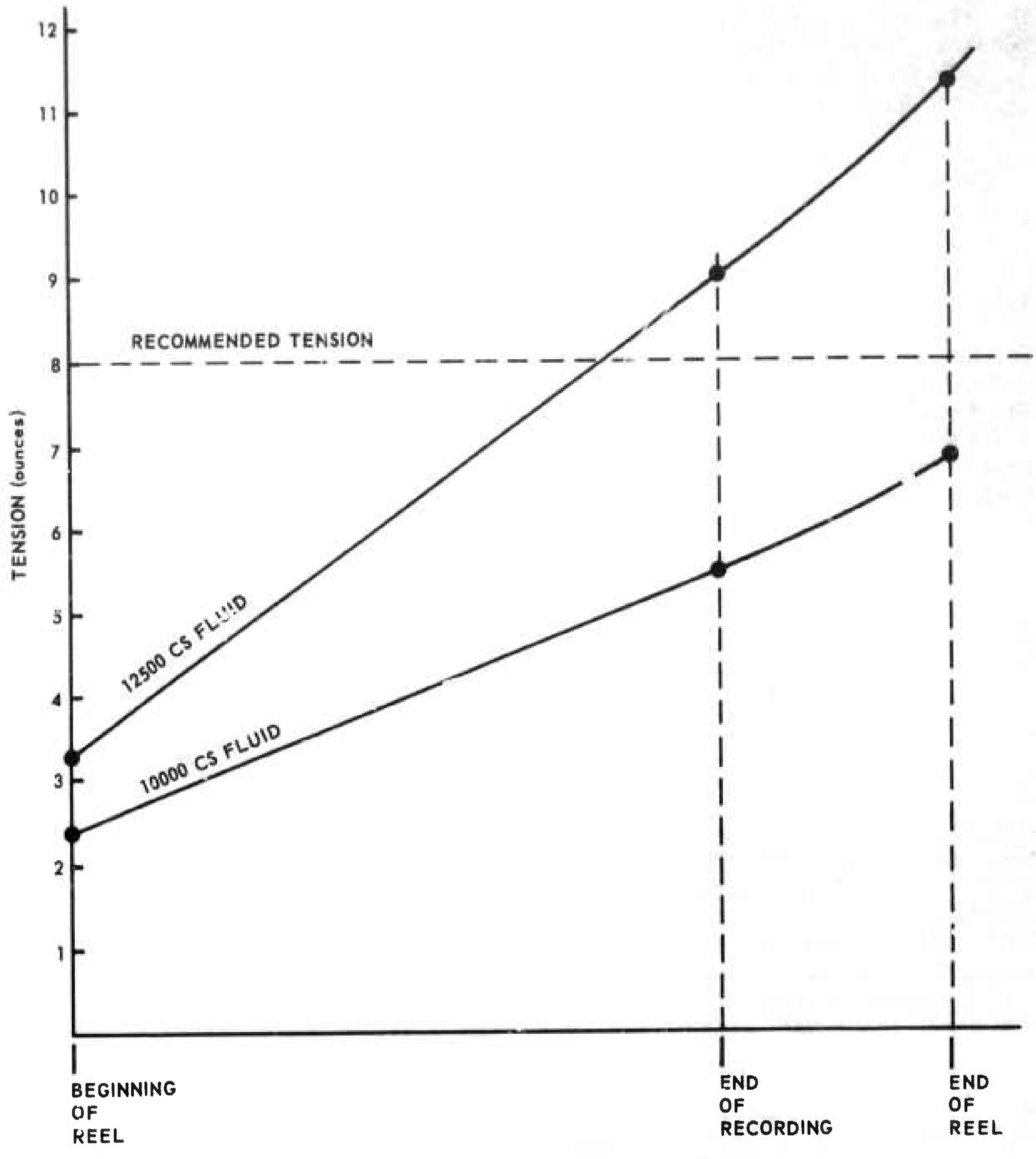
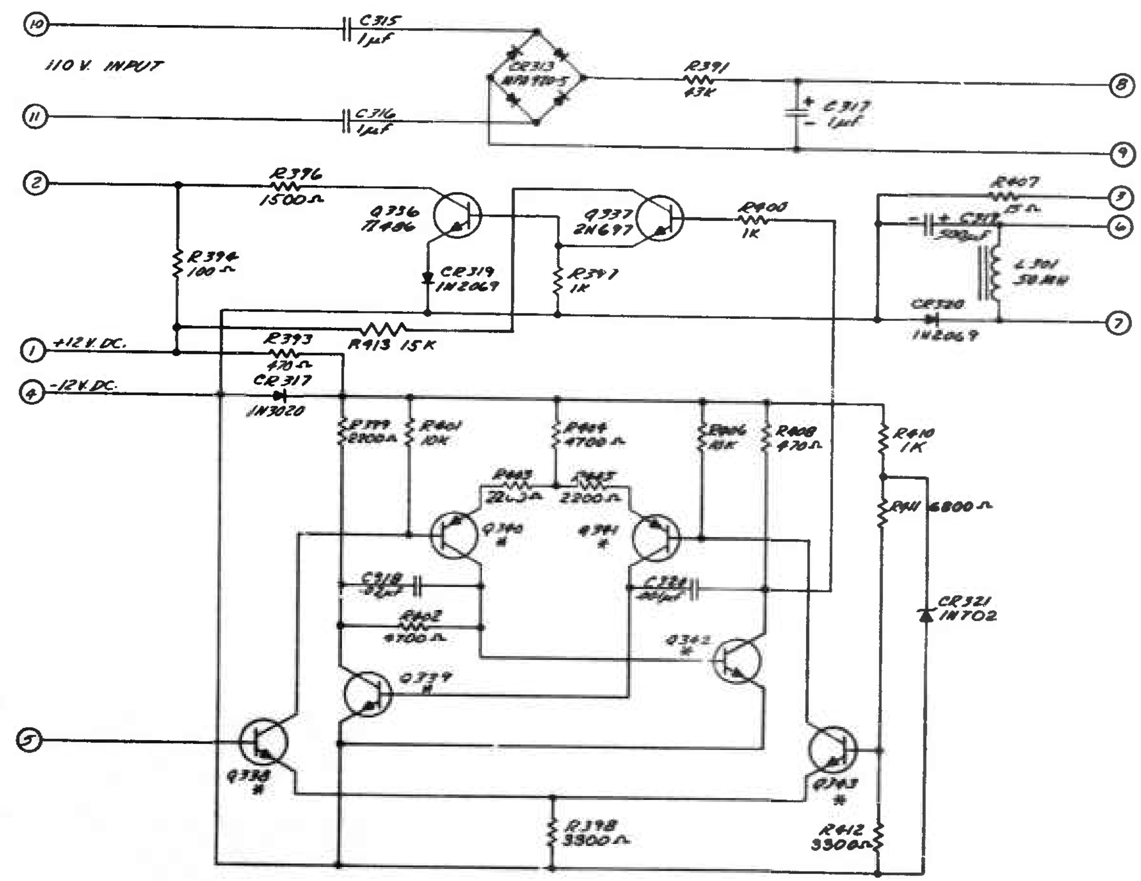


Figure 25. Tension ranges provided by the fluid in the viscous tape supply units of the Ampex Tape Recorder, Model 314



* NOTES:
1. MATCHED PAIRS OF TRANSISTORS (Q340, Q341) PER GEOTECH NO. 90-29311
2. MATCHED PAIRS OF TRANSISTORS, (Q338, Q343), (Q339, Q342) PER GEOTECH NO. 90-29309

Figure 26. Pen heat circuit in the portable system Helicorder

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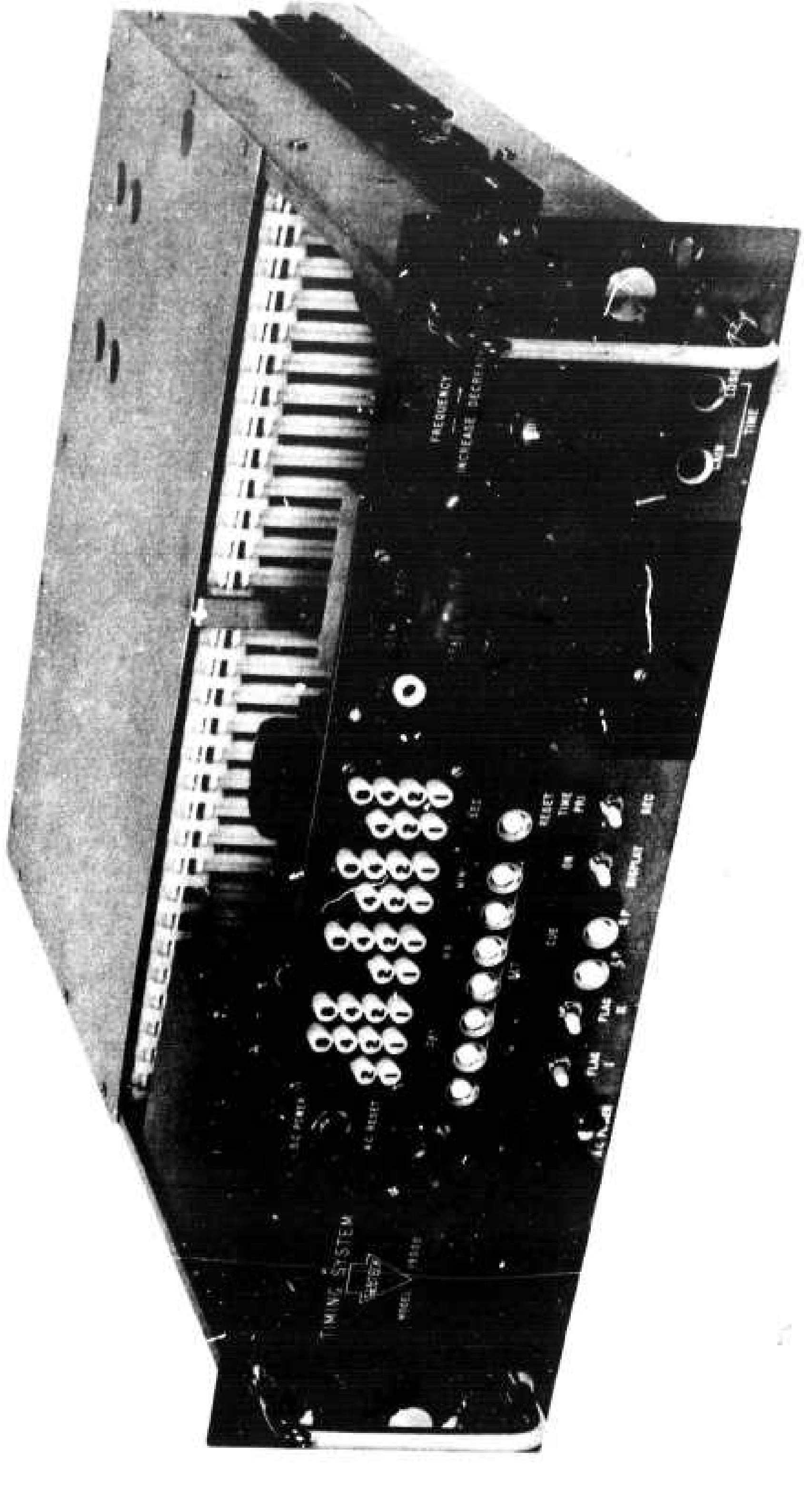

Figure 27. Timing System, Model 19000

7.6 POWER EQUIPMENT

7.6.1 Power Source, Model 28110

New battery packs for the portable systems have been designed and built to replace the silver-zinc cells previously used. The silver-cadmium cells in the new battery packs have a nominal capacity of 190 ampere hours. Eleven cells are used in the packs, and each has a nominal voltage of 1.1 volts under load. The life expectancy of the silver-cadmium cells is 3 years compared to less than 1 year for the silver-zinc cells. The cost of each silver-cadmium cell is approximately $135, which is slightly less than the cost of the silver-zinc cells; however, 11 silver-cadmium cells are required per pack to replace the 8 silver-zinc cells per pack in the previous power source.

The weight of each pack is approximately 75 pounds. The cells are enclosed in a fiberglass carrying case similar to the case used for the silver-zinc battery pack. Figure 28 is a photograph of the new battery pack.

7.6.2 Portable System Voltage Regulator

A system voltage regulator was designed and built to increase the flexibility of the portable systems. The regulator employs a solid-state series circuit that regulates at ±13 volts. Maximum input voltage is ±17.5 volts. A voltage sensing relay circuit bypasses the regulator when the input voltage is less than ±13 volts. In this way no power is consumed by the regulator when the system is being operated on thermoelectric generators or when the system batteries have reached their plateau voltage.

The unit allows the portable systems to be operated from batteries, battery chargers, or other unregulated external power sources.

7.6.3 Battery Chargers

An electronic voltage sensing circuit was installed in each portable system Battery Charger, Model 21160, to provide more accurate and positive operation of the charger cutoff relays. The sensing circuit consists of a bistable switch which actuates a relay by a change in state when the preset cutoff voltage is reached. Minor modifications to the charger were required to complete the installation of the two printed circuit boards. The charging rate for the system batteries was also decreased from 10 to 6 amperes to ensure proper charging of the silver-cadmium batteries. In its present configuration the battery charger, in conjunction with the system regulator, can now be used as a power source without requiring batteries for filtering.

7.7 FIRE PROTECTION

A prototype fire protection system has been installed in the LRSM van at Franktown, Colorado. Prefabricated kits are being furnished by the vendor for installation in eight of the remaining vans.

The system consists of a 100-pound bottle of carbon dioxide, three discharge nozzles, four detectors, an alarm bell, a pressure switch, and a power shutoff relay for the van power. The carbon dioxide bottle is stored in the closet at

Figure 28. Power Source , Model 28110

G 3080

the rear of the van. One nozzle is mounted to the rear of the instrument racks to provide protection in the area of the space heater. The second nozzle is mounted in the center instrument rack. The third nozzle is mounted in the darkroom. The detectors are "rate of rise" type sensors which actuate the system if a rapid increase in temperature occurs. A bypass orifice in the detector permits long-term temperature changes to occur without actuation of the system. Two detectors are located in the instrument racks; one is mounted in the aisle immediately forward of the racks, and the other is mounted in the darkroom. The alarm bell, pressure switch, and relay are installed at the circuit breaker box on the wall behind the racks. Upon actuation of the system, the discharging carbon dioxide trips the pressure switch, which activates the alarm circuit and shuts off the van power through the relay.

8. DATA PROCESSING

8.1 INTRODUCTION

Approximately 6000 sets of film seismograms and magnetic tapes were gathered during the 14-month period covered by this report. Added to the nearly 60,000 sets of data previously recorded by LRSM field teams, these recordings represent to VELA researchers a large source of raw data. During the past 7 years, the LRSM program has been instrumental in developing new techniques related to large-volume data processing.

Three groups, operated within the LRSM Data Reduction Section, are responsible for routinely processing both film and tape seismograms and for developing, testing, and applying new knowledge in handling and analyzing these data. The paragraphs which follow describe the activities of these groups during the period 1 April 1966 to 1 June 1967.

8.2 SEISMOLOGICAL BULLETIN

An important and continuing data processing function within the LRSM program is the analysis of data recorded by selected LRSM mobile seismological stations. These data are correlated with epicenters reported by the United States Coast and Geodetic Survey (USC&GS), and published in a monthly seismological bulletin containing the data from the selected stations. The bulletin is intended to be an aid to VELA-Uniform participants and other interested organizations in determining the extent of the earthquake data contained in the LRSM recordings. During this report period, 15 monthly LRSM Seismological Bulletins were published. Beginning 27 October 1966 a monthly bulletin containing processed data from Ice Cap, Greenland (IC-GL) was also published. Four IC-GL bulletins were published during this report period.

8.2.1 Bulletin Content

Each bulletin contains the following information:

a. Data on all phases that have been associated with epicenters reported by the USC&GS;

b. Data on epicenters listed in the bulletin as reported by the USC&GS;

c. Arrival time, period, amplitude, and distance for phases not associated with USC&GS epicenters.

Table 5 contains a review of the 15 months of processed data categorized as follows: epicenters received from USC&GS, percentage of USC&GS events recorded by the bulletin stations, number of associated and unassociated phases recorded, and the total number of phases processed.

The IC-GL seismological bulletin contains data analyzed from paper seismograms recorded at the site. Measurements are taken in the field by the team leader and reported via teletype messages. Only first arrival phases have been reported. Table 6 contains a review of the 4 months of processed data contained in the IC-GL bulletins.

8.2.2 Bulletin Stations

Table 7 is a list of LRSM seismological observatories used to compile the bulletins published during this report period. The locations of these stations are shown in figure 29.

8.2.3 Computer Techniques

A high-speed data processing system was used to process the bulletin data during this report period. The system utilizes the Automated Bulletin Processing (ABP) program available at SDL in Alexandria, Virginia, and the computer at the Geotech facilities in Garland, Texas. The computer facilities at Geotech are used to transfer the analyzed data to punched cards and magnetic tape prior to the data's shipment to SDL. The ABP program at SDL associates the data with USC&GS epicenters, makes phase identifications, calculates station-to-epicenter distances and azimuths, travel time residuals, ground motion, magnitudes, and sorts the data in accordance with the LRSM bulletin format. ABP is capable of identifying 23 phases, excluding eL, eLQ, and eLR. The total computer time required to process one bulletin is approximately 3-1/2 hours. Figure 30 shows a flow diagram of the data processing system used during this report period.

8.3 PROCESSING MAGNETIC-TAPE DATA

The Special Presentations group is responsible for processing all requests for magnetic-tape data recorded by LRSM field teams. These data are transcribed in various forms to meet the requirements of numerous routine and special studies. Data are reproduced on photographic paper and 16 mm, 35 mm, and 8-7/8 inch photographic film. By controlling both the tape and photographic recorder speeds, a wide range of playback speeds are available. During the report period, over 3,800 visual recordings were produced from magnetic tape. In addition, the group continued to prepare composite magnetic tapes of events selected for study by the Project Officer. Eight such composites were completed. The equipment consoles and the area used by the Special Presentations group are shown in figure 31. A complete listing of the equipment utilized by this group is shown in appendix 2. New methods of data presentation are continually under investigation to improve existing formats and to create new data formats.

Table 5. Data compiled in the LRSM seismological bulletins from November 1965 through January 1967

Year	Month	USC&GS epicenters	Percent of events recorded	Number of associated phases	Number of unassociated phases	Total No. phases
1965	November	387	59.5	2052	846	2898
	December	375	60.1	1606	634	2240
1966	January	366	48.1	1033	617	1650
	February	367	65.4	2485	931	3416
	March	432	77.1	3003	1483	4486
	April	402	63.7	3126	1628	4754
	May	439	65.4	2882	1930	4812
	June	448	58.0	3672	1663	5335
	July	364	68.1	3342	2782	6124
	August	471	75.0	4517	6979	11496
	September	418	59.8	2233	2141	4374
	October	397	62.0	1995	1340	3335
	November	367	61.3	2485	965	3450
	December	351	56.4	2163	1179	3342
1967	January	495	64.5	3691	1560	5251
TOTALS	15 months	6079	avg 63.0	40285	26678	66963

Table 6. Data compiled in the IC-GL seismological bulletins from 27 October 1966 through 31 January 1967

Year	Month	USC&GS epi-centers	Percent of events recorded	No. of associ-ated phases	No. of unassoci-ated phases	Total No. phases
1966	October	62	45.2	28	65	93
	November	367	28.1	103	231	334
	December	321	32.7	105	226	331
1967	January	465	35.5	165	262	427
TOTALS	4 months	1215	35.4	401	784	1185

Table 7. LRSM seismological observatories used to compile seismological bulletins for November 1965 through January 1967

Station	designator	Station	designator
AD-IS	Adak, Aleutian Islands	MN-NV	Mina, Nevada
AX2AL	Alexander City, Alabama	MO-ID	Mountain Home, Idaho
BE-FL	Belleview, Florida	NP-NT	Mould Bay, Northwest Territory
FK-CO	Franktown, Colorado	PG-BC	Prince George, British Columbia
GV-TX	Grapevine, Texas	RK-ON	Red Lake, Ontario
HN-ME	Houlton, Maine	SI-BC	Smithers, British Columbia
IC-GL	Ice Cap, Greenland	SV3QB	Schefferville, Quebec
JP-AT	Jasper, Alberta	SW-MA	Sweetgrass, Montana
KC-MO	Kansas City, Missouri	WH2YK	Whitehorse, Yukon Territory
KN-UT	Kanab, Utah	WN-SD	Winner, South Dakota

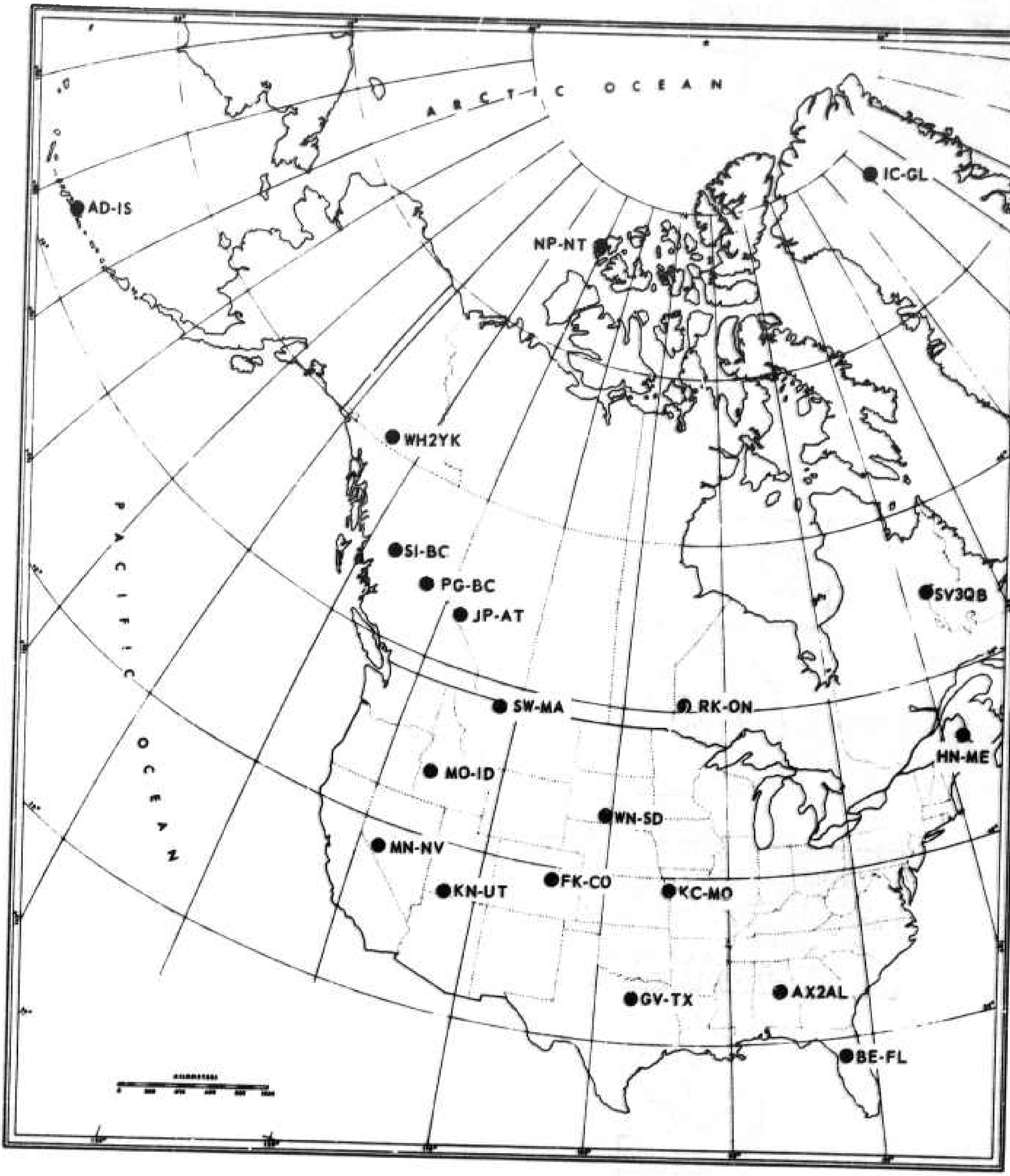

Figure 29. LRSM seismological bulletin sites

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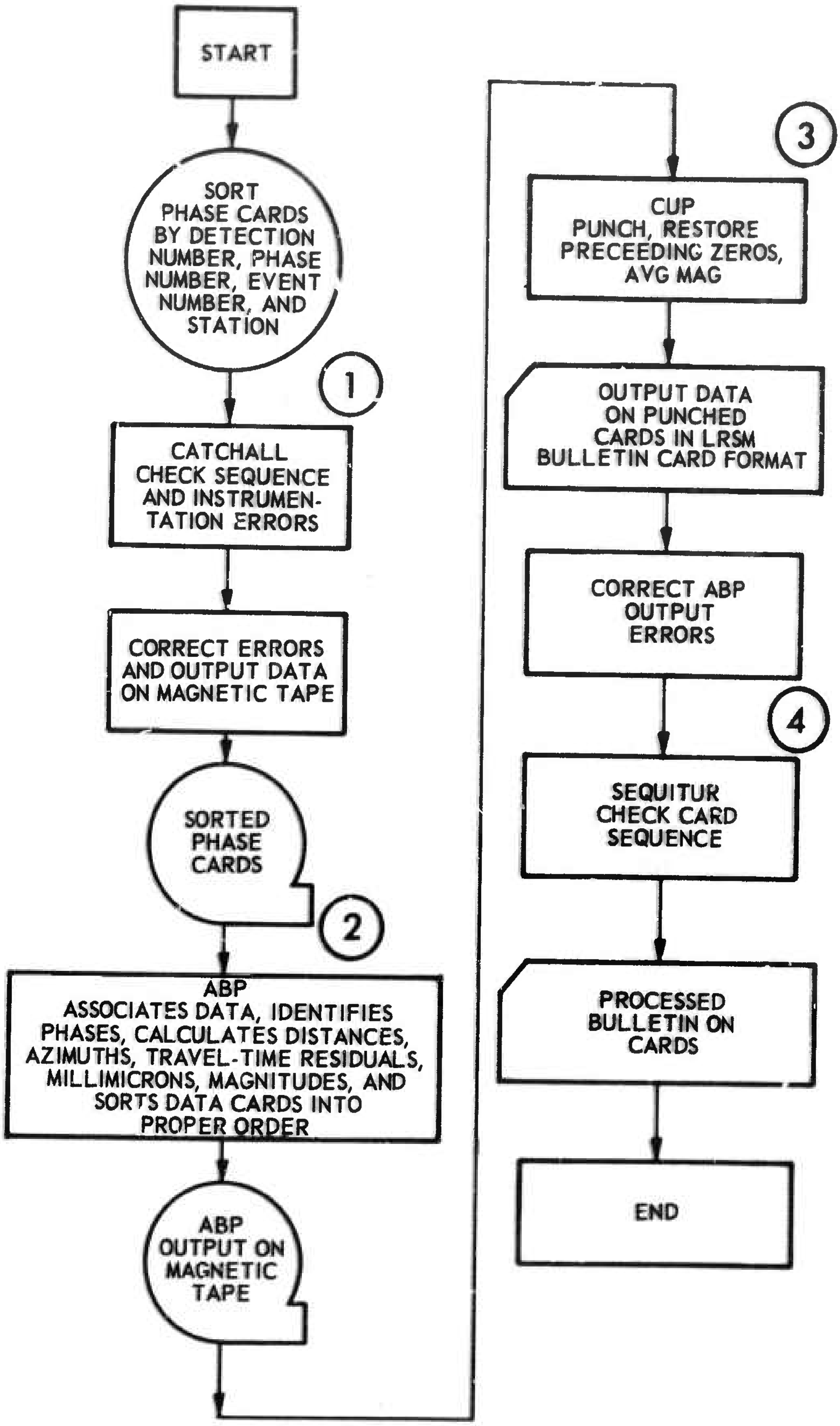

Figure 30. ABP LRSM bulletin processing system

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G 1748

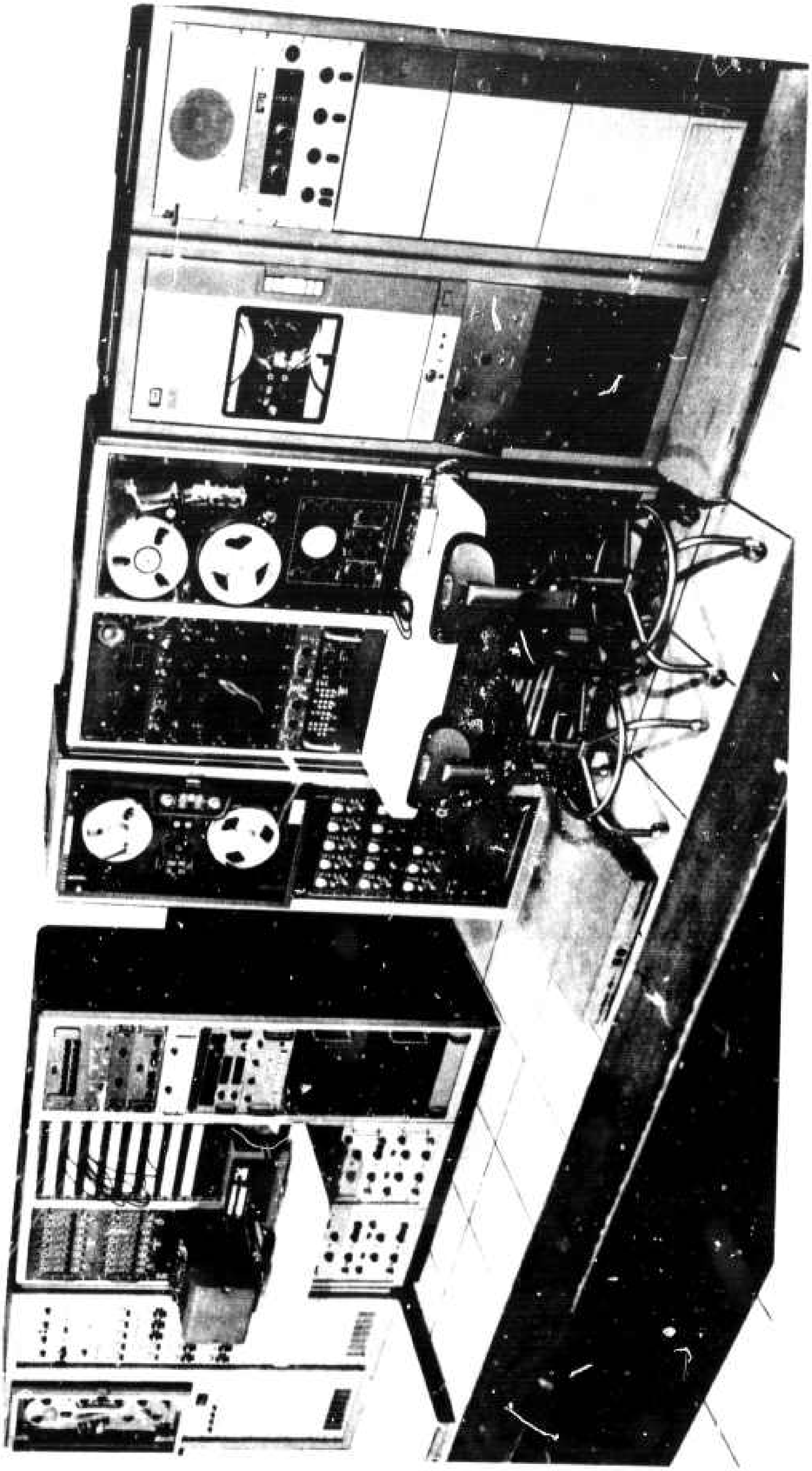

Figure 31. Spe al presentations system

8.3.1 Auxiliary Equipment

During this report period, several instruments were redesigned and rebuilt to improve the operations of the data processing system.

a. Eight-channel dc amplifier. This unit, shown in figure 32, was rebuilt to stop crossfeed and 60 cps pickup. This differential amplifier is constructed on standard printed circuit boards. The input impedance is variable from 500 ohms to 100 kohms. The output impedance is less than 50 ohms. This amplifier is primarily used as a galvanometer driver, but a number of additional applications have developed. These applications include: impedance matching, signal isolation, and signal inversion.

b. Oscillograph unit. The oscillograph used during playout of portable systems data was modified to improve the quality of the film records. Improvements were made in trace resolution and in the controls used for fine adjustment of the optics during setup. This unit is shown in figure 33.

c. High-speed camera. This camera was built to Geotech specifications by General Atronics Corporation. To date, 70,000 feet of SP data and 5,000 feet of LP data have been processed. Figure 34 shows this camera in operation in the data processing system.

d. Analog spectrum analyzer. Approximately 100 spectra have been processed for various special studies within the LRSM program during the past 14 months. Figure 35 shows the analog spectrum analyzer.

8.4 SEISMIC NOISE SURVEYS

8.4.1 General

Noise studies give an indication of the properties of the seismic noise found in a given area. A completed noise survey for a given LRSM site includes: a curve showing cumulative probability distributions of amplitudes; a histogram showing percentage of occurrence of indicated periods; and a noise spectrum curve showing the average noise amplitude in millimicrons, corrected for the system response and plotted as a function of period.

Noise studies conducted from 33 sites were composited into Technical Report No. 67-19, Seismic Noise Survey No. 3, Long-Range Seismic Measurements Program. This report is scheduled for publication during July 1967.

8.4.2 Computer Processing and Plotting

A study program was initiated to investigate the feasibility of using an on-line X-Y plotter to compute and plot the data points, curves, and histograms of noise studies. The program was 80 percent complete on 31 May 1967; further verification of the equations used will be required before the results of the study are known. If the study proves successful, each step in the process of publishing a noise study will be performed by computer processing except for the taking of the samples by the analysts. This program will significantly reduce the time required to process noise studies and the data will be plotted more accurately

G 3082

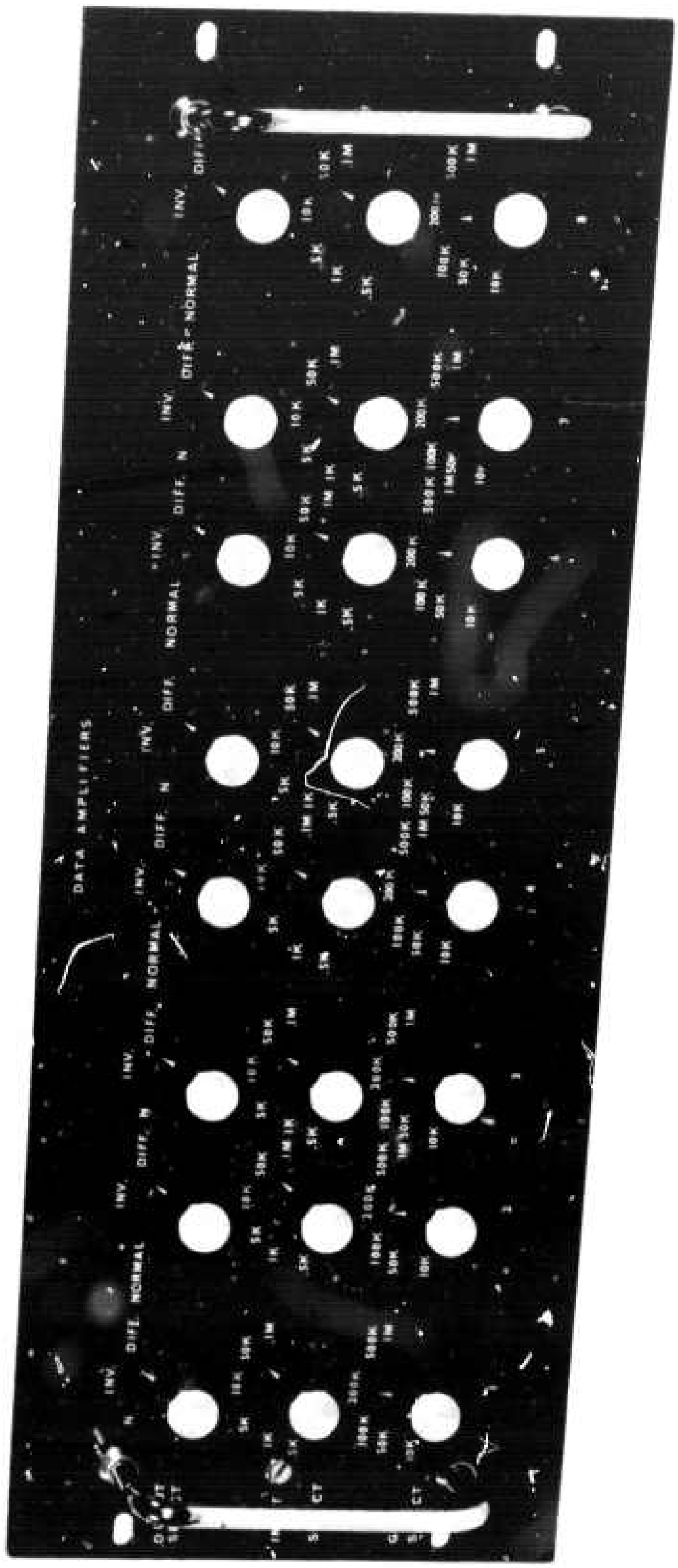

Figure 32. Eight-channel dc amplifier

Figure 33. Oscillograph unit

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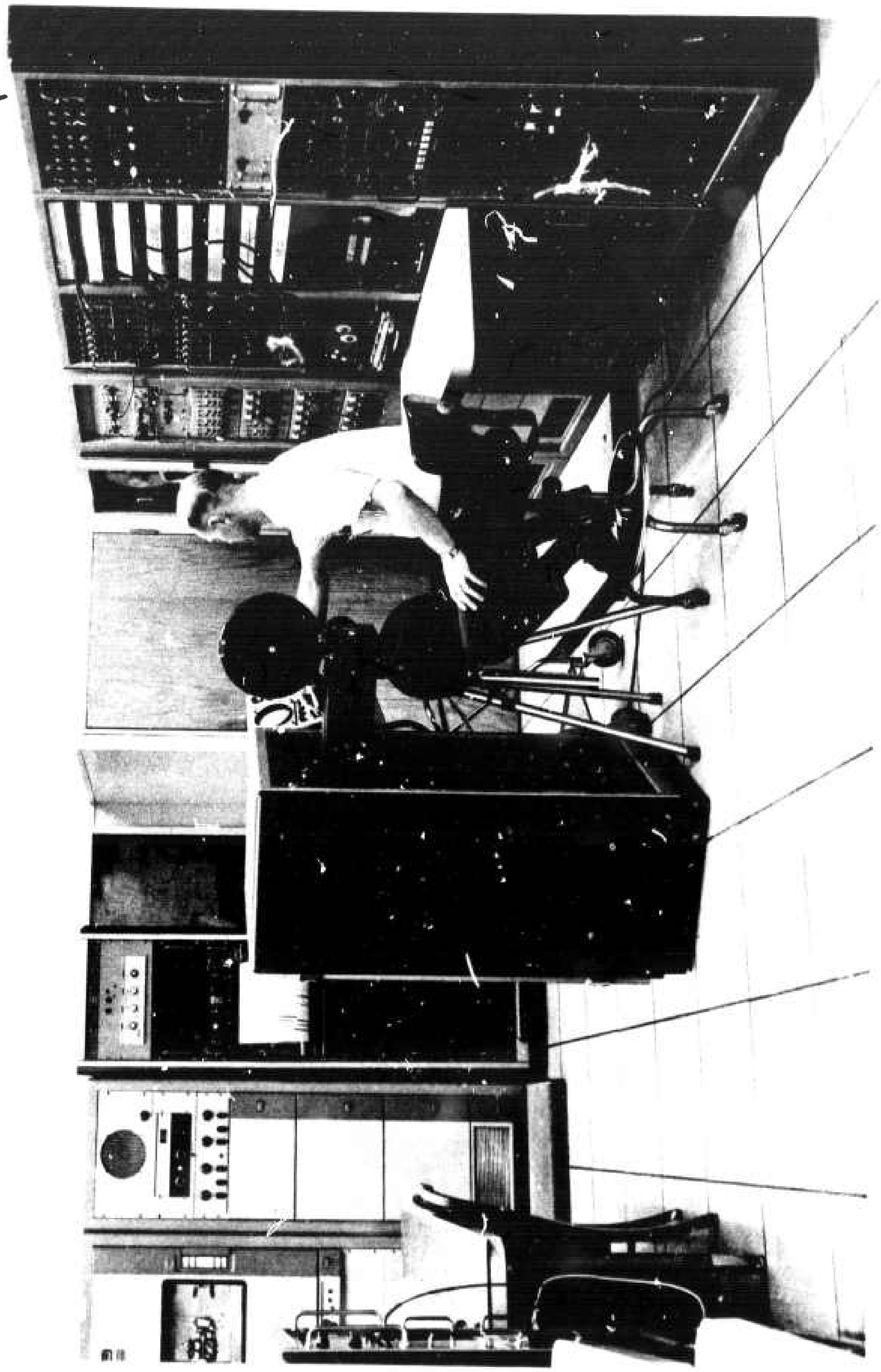

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Figure 34. Portable system's data processing system in operation

Figure 35. Analog spectrum analyzer

G 3085

than can be done by the present "best-fit" manual methods. Figure 36 shows a preliminary sample playout of a cumulative probability distribution of amplitudes curve processed on an X-Y plotter. As the data points are plotted, a least-squares equation computes the smooth curves. The scale and all labeling can also be drawn by the plotter.

It is anticipated that raw data (noise amplitudes in mm) could be processed and distributed in standard noise study format in 1 day when requested by the Project Officer.

8.4.3 Digital Format Noise Surveys

Seismic noise recorded by vertical SP seismographs at 10 LRSM stations was surveyed to compare the standard LRSM methods with an integrated power density spectra method. The objective of this study was to explore a possible alternative or supplemental noise study technique based on the power spectral density function described by Blackman and Tukey.[1]

Background noise over a period of 1 or 2 months at each station was chosen for comparison. Two hundred noise samples were measured from each site in computing the cumulative probability distribution of amplitudes curves (popularly known as the "S" curves) for the standard LRSM survey. Two noise segments, approximately 3 minutes in length, were selected for the power density spectra study. The spectra density of the 1.4- to 0.3-second period range was summed for each segment and the average ground motion in mμ was determined. From this value, an average background noise level from each site was obtained. This was compared with the 50 percent level from the "S" curve of the same site.

Both methods produced similar values of background noise in mμ. This indicates the two methods are empirically related, even though no theory is known to exist which would explain the relation. It was noted the power spectrum furnishes considerable valuable supplemental information to that gained by the standard LRSM method. A technical report of this survey will be published during August 1967.

8.5 DATA CATALOG

A program was written and tested which generates the LRSM Data Catalog directly from the cards prepared for the EDP operations log program. The February 1967 catalog was the first published using this program.

Outage time for each data channel will be entered in the catalog to the nearest 1/10 hour rather than the nearest 1/2 hour, as was previously done. Thus, catalogs which are five times more accurate are now published twice as fast using the computer program to calculate and list the outage times. It is anticipated that each catalog will be distributed within 30 days of the end of that same month.

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[1]Blackman, R. B., and Tukey, J. W., 1959, The measurement of power spectra: Dover Publications, New York, N. Y.

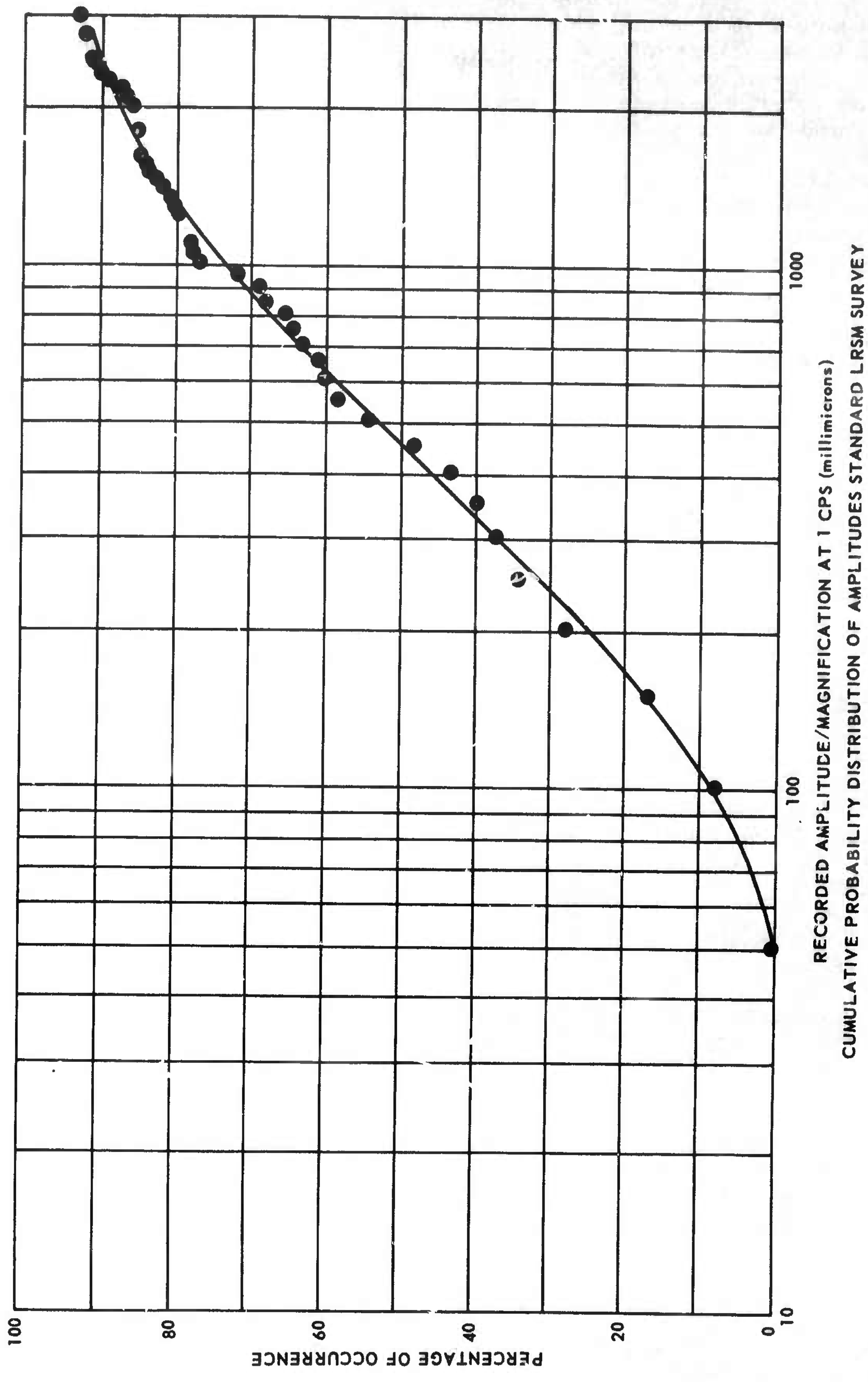

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Figure 36. Sample noise study curve processed on an X-Y plotter

A recent addition to the catalog is a listing of the operational periods and locations of each of the portable systems operated by LRSM. This information is shown monthly in table 1, LRSM site information of each catalog. An EDP operations log for the portable systems is being designed for evaluation by the systems' operators. When such a log is accepted and put into general use, it will be possible to list the outage time of each portable system in the same manner as is now done for the mobile observatories.

8.6 SHOT REPORTS

Two reports were published on events selected by AFTAC, providing the data required by the standard 45-day shot report format. The events reported were STUTZ and CHASE V.

9. SPECIAL PROJECTS

9.1 GENERAL

A variety of scientific studies were conducted during this report period. The two principal areas of concentration were the study of special events monitored by the LRSM portable systems, and the investigation of LP signals, instrumentation, and data processing techniques. The various experiments in which the portable systems participated are outlined in section 9.2: the several projects involved in the LP effort are discussed in section 9.3. Section 9.4 describes three studies that do not fit into either category.

9.2 INTERPRETATION OF LRSM PORTABLE SYSTEM'S DATA

a. Seismic Measurements from ARPA Shot Series at Mono Lake, California (TN 16/66). Between 2 September and 9 September 1966, a series of 12 detonations was conducted at a single spot in the waters of Mono Lake, California. The series consisted of three shots each of four types of chemical explosive - TNT, nitromethane, slurry (containing ammonium nitrate), and anoil (ammonium nitrate plus 5.8 percent fuel oil). All charge weights were nominally 1 ton. The purpose of the series was to establish whether any differences exist in the energy releases or seismic signals from these four types of explosive. The shots were monitored by four LRSM portable systems and the LRSM mobile observatory at Mina, Nevada.

Two of the 12 scheduled shots were misfires. The remaining 10 shots produced seismic signals which were essentially identical in character, whether viewed in the time or frequency domains. The amplitudes of the seismic signals varied about their average value by as much as ±20 percent, although not in a way that allowed simple characterization of the four different explosive types. The 3 TNT and 3 nitromethane detonations produced amplitudes that were essentially the same, although the nitromethane amplitudes averaged out slightly higher overall. One of the slurry shots created amplitudes commensurate with the nitromethane data, but the other resulted in amplitudes about 20 percent lower.

Both of the anoil explosions produced anomalously low measurements, one about 7 percent below and the other 30 percent below the overall average.

b. Participation in Project EARLY RISE (TR 66-116). The portable systems occupied and recorded data from 77 temporary sites during the 21-day Project EARLY RISE experiment. The systems proved to be well suited for the quick set-up time and the frequent moves that were required by the shot schedules in this program. Site selection was performed by the systems' operators rather than by an advance site selection team. The tolerance on site locations was ±5 km.

The data recorded on magnetic tape during the experiment were played out on a visual recorder and sent to the project investigators. Data recorded by the 16 LRSM mobile observatories were also made available. A preliminary plot of travel times versus distance (from near-regional to teleseismic distances) over two profile lines in Canada indicated a constant P-wave velocity of 8.46 km/sec.

c. Participation in Project STERLING (TN 5/67). The LRSM program was assigned the task of operating 4 portable seismograph systems and 2 mobile seismological observatories during Project STERLING. This project was devised to further test the theory of decoupling. The project involved two detonations in the Tatum Salt Dome in Mississippi - a chemical calibration shot on 17 November 1966 and the STERLING nuclear event on 3 December 1966.

Seismograms and spectra of the Project STERLING events recorded by both the mobile observatories and the portable systems were included in the report. In addition, a careful analysis was made of the SP signal recorded at the LD-MS site on 3 December, which appeared to be anomalously large. Various checks on the recording instrumentation at LD-MS, plus an analysis of the particle-motion pattern of the surface group recorded there, produced no reason to suspect that the signal was not generated by the STERLING event.

d. The Llano Uplift Experiment. Data were recorded in the Llano Uplift area of West Texas for a study of the effect of near-surface sedimentary layering on the character and amplitude of teleseismic P waves. Five portable systems occupied seven sites in that area from approximately 17 April through 23 May 1967. The recording sites are shown in figure 15, superimposed on a contour map of the granitic basement which outcrops at the southeast end of the recording line. All three SP seismometers in each system were operated in the vertical position for cross-checking. During the recording period, seismic activity was monitored by means of daily reports from the Tonto Forest, Uinta Basin; and Wichita Mountains Seismological Observatories. The total number of large-amplitude teleseismic signals obtained was approximately 25, including 3 PKP phases.

At the close of the contract period, interpretation of the data had just begun. Preliminary analysis indicates a much more complicated picture than was anticipated, as signal amplitudes and characteristics appear to be responding to subtle changes in signal frequency and/or travel path. One of the first steps in interpreting the data will be to study the signals in the frequency domain. Shallow refraction surveys of the recording sites are to be performed to obtain the thicknesses and velocities of the near-surface layers.

9.3 LP STUDIES

a. Characteristic Periods of LP Body Waves (TN 10/66). A statistical survey was conducted to determine the predominant, or characteristic periods associated with P and S waves (initial phases) recorded by the LRSM LP seismographs over a 30-month period. The findings of the survey were presented and discussed in Technical Note 10/66. It was expected that the information obtained would be useful in the planning of future LP instrumentation and data processing techniques.

Based on over 2800 period measurements, the characteristic, or predominant, period of P phases (initial P arrivals) recorded on LRSM LP seismographs was 17 seconds. Over 60 percent of all LP P phases reported in the LRSM bulletin had periods between 15 and 20 seconds. On the basis of an equivalent number of measurements, the characteristic period of S phases was 20 seconds. Over one-half of all LP S phases in the LRSM bulletin had periods between 17 and 22 seconds.

b. PHILTRE - A surface wave particle motion discrimination process. A computer program was written to implement a digital procedure for extracting LP surface wave signals from microseismic background noise. The process is a deterministic one and amounts, basically, to frequency filtering using measurements on particle motion to shape the filter response. The PHILTRE program examines all three components of earth motion in the frequency domain and weights each harmonic according to how closely the particle motion pattern corresponds to the theoretical time-space pattern for Love or Rayleigh waves. The time-domain traces are then reconstructed using the weighted coefficients. Preliminary tests on the process were encouraging, as it materially improved the signal-to-noise ratios of surface waves which were barely discernible on the unprocessed seismograms. A subroutine was added to the program which provides a usable estimate of the peak amplitudes of surface wave signals passed by the process.

The development of the PHILTRE process was reported in technical memoranda dated 6 January 1967 and 28 February 1967, plus a third memorandum scheduled for distribution in July 1967. A technical report summarizing the entire project is being prepared.

A demonstration of PHILTREing is provided in figure 37.

c. Operation of long-period seismographs in deactivated missile silos. An experiment was conducted in the early part of 1967 to evaluate deactivated missile silos as suitable environments for the operation of LP seismographs. One of the principal causes of noise in LP systems is known to be the minute fluctuations in temperature and pressure associated with an unstabilized atmospheric environment. It was thought that the high degree of isolation available at the bottoms of missile silos, which extend to depths of 160 feet, might provide an extremely stable thermal and barographic ambient which would facilitate the noise-free operation of LP seismographs. Previous LRSM experience at mine sites and at La Paz, Bolivia (N. M. Warren, 1966), had indicated that appreciable improvement could be obtained by moving LP seismographs into natural or man-made earth cavities.

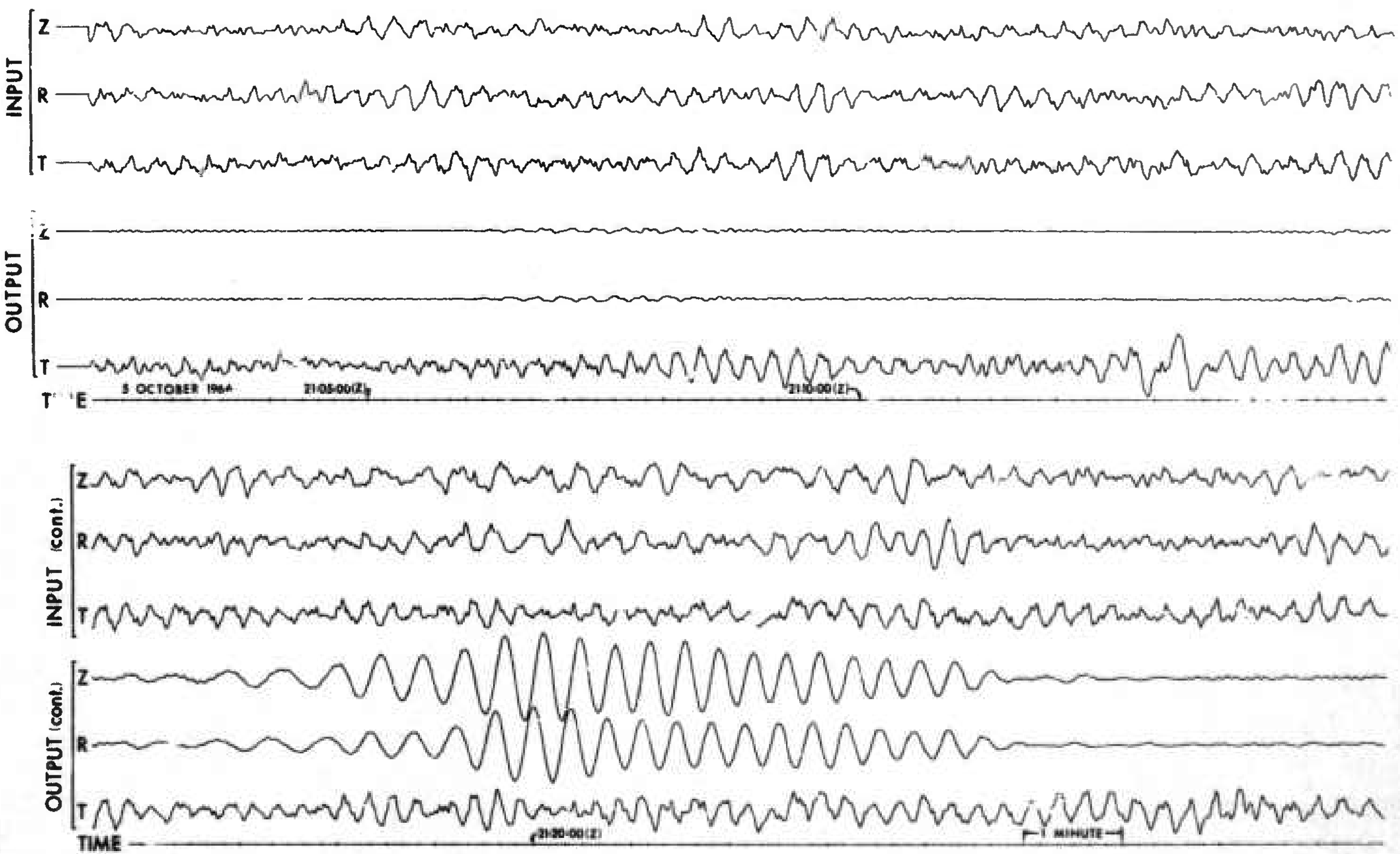

Figure 37. Love and Rayleigh waves from a magnitude (m_b) 4.7 earthquake in the West New Guinea region, extracted by particle-motion PHILTREing. These signals were recorded at Prince George, British Columbia (PG-BC) on October 5, 1966. Epicentral distance was about 97°

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For a period of over 6 months, 2 deactivated missile silos, 1 in Idaho and the other in Colorado, were occupied by LRSM teams. Two complete three-component LP systems were operated at each site, one at the bottom of the missile silo and the other on the surface, installed in accordance with standard LRSM procedures. The capability of observing both these sites at the same time, and more importantly of being able to cross-check the surface and silo instruments against one another, made it possible to arrive at several firm conclusions which would otherwise have been tenuous, if not impossible. The most significant result of the experiment was that missile silos are an inherently poor environment for LP seismographs because such silos are deliberately placed in incompetent formations or rock debris. The effects of these nonrigid surface layers are to produce abnormally high-amplitude microseismic noise in the horizontal plane and to make the horizontal seismographs highly susceptible to local earth loading (tilt) effects. Gusting wind was found to be a prime source of such tilt noise, as illustrated in figure 38. A technical report is being prepared.

d. Statistical investigation of LP noise spectra. A study was begun of the short-term stationarity of the amplitude spectrum of LP microseismic noise. Preliminary measurements indicate that a frequency-domain noise prediction and cancellation technique may be feasible. The initial results of such a process are expected to be available in September 1967.

9.4 MISCELLANEOUS PROJECTS

a. Characteristics of Instruments and Seismic Noise in Two Shallow Holes at Hysham, Montana (TR 66-50). During August and September 1965, a Geo Space Model HS-10-1/ARPA seismometer, and a Deep-Hole Seismometer, Geotech Model 11167, were operated in two adjacent 500-foot holes at the center of LASA subarray F3 (near Hysham, Montana). The two seismographs were operated concurrently at six different depths from 71 to 500 feet. A reference SP vertical Benioff seismograph was operated on the surface. Signal amplitudes were measured at all depths to cross-check seismograph magnifications, and noise samples were selected representing five arbitrary categories of noise situation - nighttime calm, daytime calm, traffic, moderate wind, and high wind. Power density spectra were computed from the noise samples, and the ratios of the spectra in the hole to those on the surface were obtained. The report discussed the instrumentation, operation, and data processing procedures utilized and presented the results of the data analysis. It was found that both seismographs operated satisfactorily and recorded equivalent data. The data showed that the attenuation of seismic noise at shallow depths is an erratic, nonlinear function of noise amplitude which depends heavily upon the frequency and type (source) of the disturbance. Traffic noise and microseismic background are attenuated increasingly as either depth or frequency increases, 5 cps noise at 500 feet having an amplitude about 18 dB below the amplitude of the surface noise. Wind-generated noise in the pass band from 0.5 to 3.0 cps is strongly attenuated at a depth of only 71 feet, with little additional improvement to be obtained at the 500-foot depth. At all depths, an improvement in noise level of more than 15 dB (at 1 cps) was realized during periods of high-wind velocity (20-40 mph). During the months surveyed, the dominant earth noise consisted

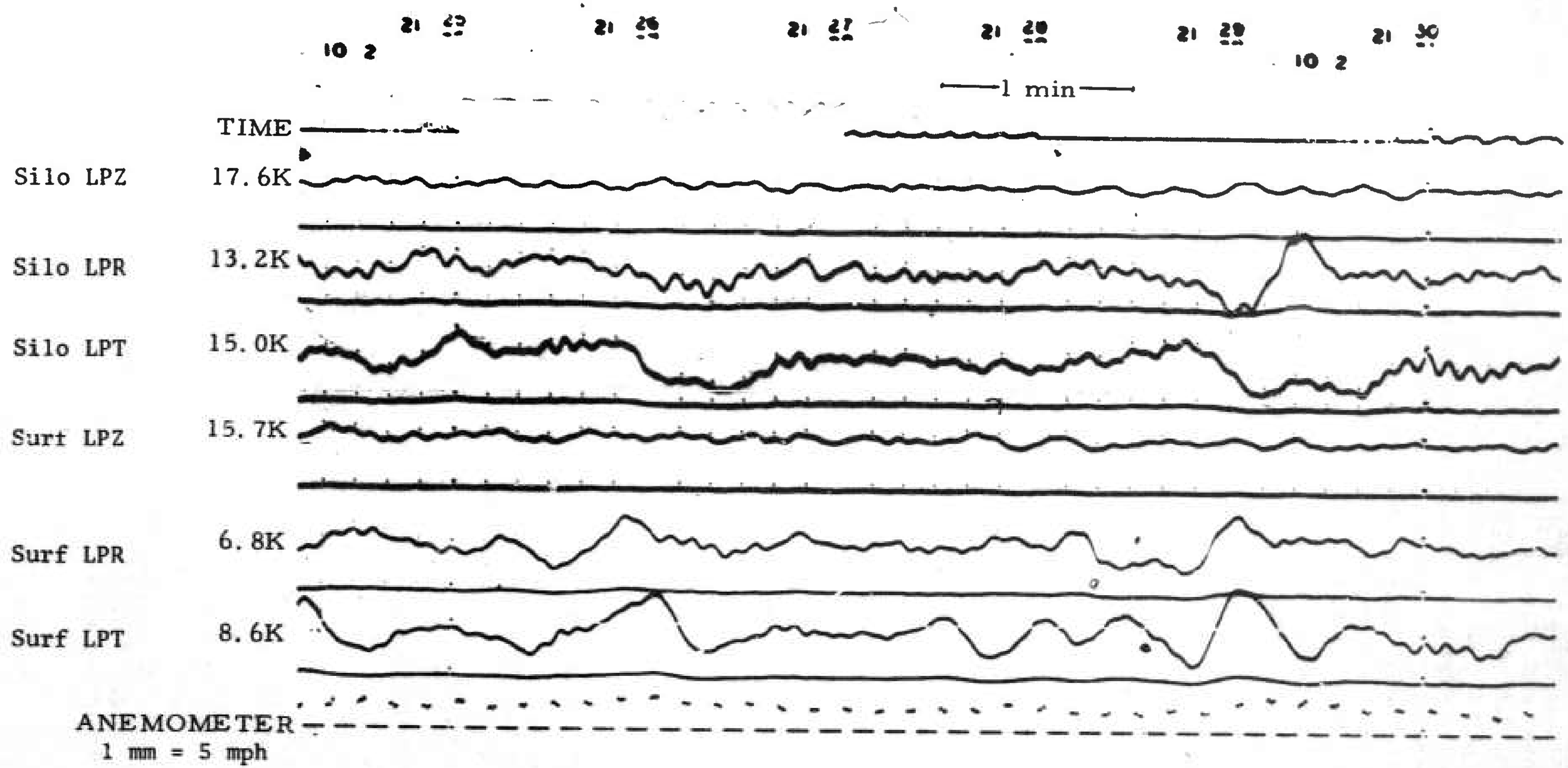

Figure 38. Coincidence of wind activity at Mountain Home, Idaho (MC-ID) with tilt noise on the horizontal long-period seismographs

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of a stationary spectral peak centered about a frequency of 0.3 cps. A small but stable local peak in the noise spectrum was also found at about 2 cps.

b. Statistics Associated with the Detection of Body and Surface Waves from Earthquakes and Underground Detonations (TR 66-83). A statistical survey of the LRSM Seismological Bulletin was made to determine the chances of detecting SP P, LP P, LP S, and LP surface waves from earthquakes at four different LRSM sites - LC-NM, MN-NV, RK-ON, and DH-NY. The probabilities were tabulated as joint functions of epicentral distance and magnitude, based on hypocenter information supplied by the USC&GS. A similar survey was made of 19 LRSM Shot Reports to determine the frequency with which these phases have been detected from underground detonations, all LRSM stations considered. An attempt was made to compare the earthquake and detonation statistics. The results showed that surface waves from earthquakes are identified on LRSM LP seismograms much more frequently than body waves from the same events, by a factor of about five (see figure 39). Also, the probability of an earthquake being detected is much more affected by its magnitude than the distance to the recording site. A statistical indication was found that there is a difference between earthquakes and explosions in their propensities to emit body-wave energy in the LP band.

c. The Relationship Between Signal Amplitudes and Surface Geology at the Tonto Forest Extended Array (TR 67-37). A study was made of 48 SP teleseismic P waves mutually recorded at six LRSM sites in Arizona. The amplitudes of corresponding signal excursions were measured from the vertical traces, and the mean amplitude at each site was computed. The mean amplitudes ranged from 37.5 mμ at Sunflower (SN-AZ) to 66.3 mμ at Jerome (JR-AZ). Shallow refraction surveys were conducted at all six sites to determine the thicknesses and compressional wave velocities of the surface formations. Analysis showed that the mean signal amplitudes exhibited a good inverse linear relationship with the square roots of the compressional velocities of the strata directly supporting the vaults, in accordance with the concept of seismic impedance. This relationship is illustrated in figure 40. The SN-AZ vaults were emplaced in Pre-Cambrian granite while the JR-AZ vaults were in a Quaternary alluvium valley.

For any one event, the relative amplitudes at the six sites varied considerably from the mean relationship described above. Tests on some of the data indicated that the variability could not be simply ascribed to differences in azimuth of arrival.

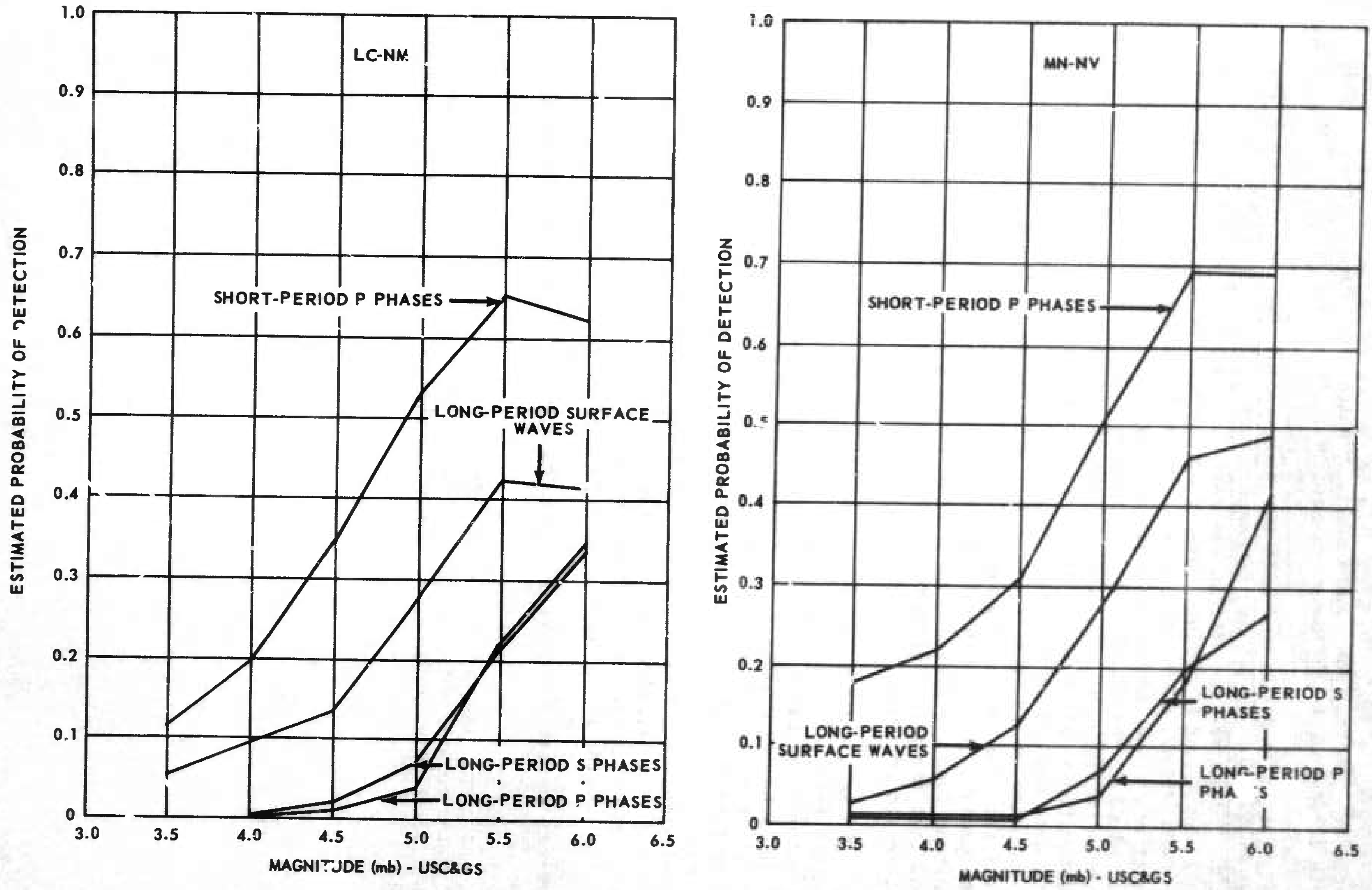

Figure 39. Estimated earthquake detection probabilities as functions of magnitude, LC-NM and MN-NV

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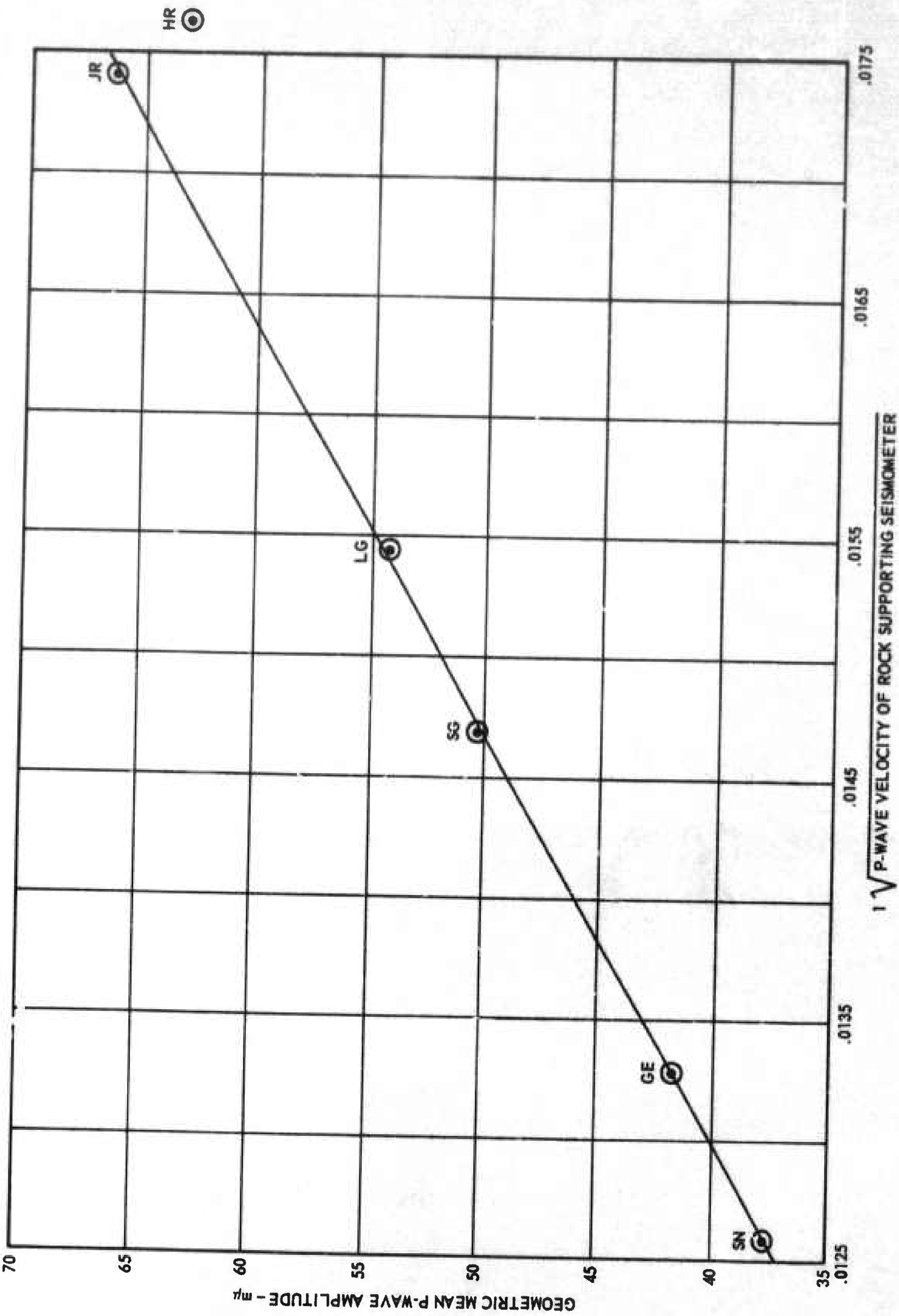

Figure 40. Correlation of mean signal amplitudes at the TFSO extended array sites with velocities of the surface layers

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APPENDIX 1 to TECHNICAL REPORT NO. 67-50

SURVEY OF EQUIPMENT DESTROYED BY FIRE AT HN-ME

ITEMS DESTROYED IN FIRE (MAJOR EQUIPMENT)

Geotech Model No.	Unit	Group No.	Mfr	Model No.	Mfr S/N	Contract	Govt S/N
	Function Gen	027	Hwltpkd	202AR	8837	41694	01104
90 09000 00	Em Cal Control	032	Geotech	09000	38	41694	01862
	Fiducial Control	033	Geotech	17086	18	12145	
90 07695 00	B1 Cal Control	035	Geotech	7695A	18	41694	00379
90 09300 00	Cal Contl Tape	037	Geotech	09300	117	41694	02154
90 09212 00	Calibratr Tape	039	Geotech	09212	14	41694	01975
66 109 0503	Oscilloscope	041	Tektrnx	00503	1161	41694	00881
90 05791 00	Data Cntl Frame	048	Geotech	05791	61	41694	01390
90 04983 00	Helicorder Amp	050	Geotech	04983	189	41694	01477
				4983	211	41694	01486
	Film Recordr SP	053	Geotech	1301A	19	41694	00422
	Film Recordr LP	054	Geotech	1301A	60	41694	01572
90 02484 02	Helicorder	063	Geotech	2484-2	163	41694	01451
	Tape System	075	Ampex	00314	102	41694	00949
	Mda Freq Std	088	Ampex	65675-300			00246
	Mass Pos Contrl	090	Geotech	7798A	41	41694	01510
	Timing System	096	Geotech	5400M	51	41694	02282
	Chronometer	101	Hamiltn	OM 21	12488	41694	02029
	Receiver	108	Hamrlnd	R-542	124	41694	00229
	Rad Tm Sig Conv	117	Geotech	5390A	73	41694	00817
	Dc Ac Inverter	124	Geotech	10050A		41694	
	Pwr Control	130	Geotech	08643	10	41694	01260
	Reg Monitor	131		19020	33	12145	00081
	V Reg Inv	140	Gen Rad	1570-ALR	3855	41694	00760
	Charger	141	Geotech	09900	6824	41694	00848
				9900	6884	41694	01225
	Film Projector	145	Alpex	PRTBL 35MM		41694	01143
	Vtvm	162	RCA	WV98B	71124	41694	01554
	Megger	163	Rowan	00405	4099	12145	00108
	Vom	164	Triplet	00630	154335	41694	00065
	Van	177	Geotech	08513	235	41694	00735
	Film Viewer	207	Geotech	20003		12145	X-629

ITEMS DESTROYED IN FIRE (TOOL LIST)

Geotech Catalog No.	Description		Mfr	Part No.	Contract No.	Quan
57 020 8272	Aligument tool	kit		GC-8272	41694	1
	Cutters					
57 110 4501	Diagoaal 4 1/2 in.	kit		4501-4-1/2	41694	1
57 110 4502	Diagonal 6 in.	kit		4501-6	41694	1
57 110 4501	Diagonal 8 in.	kit		228-8	41694	2
57 270 2500	Drill hand kit	kit		2500MF	41694	1
57 010 0108	File, flt 8-in.	kit			41694	1
57 080 2342	Flex fioger	kit		2342	41694	1
57 080 1265	Hacksaw	kit		99MF	41694	1
57 150 0101	Hammer, claw	kit		101-1/2	41694	1
57 150 0022	Hatcbet, hammer	kit		22	41694	1
57 350 0022	Knife, elect	kit			41694	1
52 060 0134	Level, cross tst	kit	Starret	00134	41694	1
	Brace, wood				41694	1
	Bit, 3/4 wood				41694	1
	Pliers					
57 120 1631	Hook hill	kit		CC-1631	41694	1
57 120 0083	Lg nose 4 1/2 in.	kit		83	41694	1
57 120 1561	Lg nose w-cuttr	kit		CC-1661	41694	1
57 120 0007	Vise grip 7 io.	kit		7R	41694	1
57 140 0730	Punch 15/16 io.	kit	Greenle		41694	1
	Screwdrivers					
57 260 0186	Cabinet 6 in.	kit	Xcelite	R-186	41694	1
57 260 0188	Cabioet 8 in.	kit	Xcelite	R-188	41694	1
57 260 0810	Cabinet 10 in.	kit	Xcelite	R-810	41694	1
	Heavy dty 4 in.	kit			41694	1
57 260 1006	Heavy dty 8 in.	kit	Stanley	01006	41694	1
57 260 0668	Offset 1/8 io.	kit			41694	1
57 260 0671	Offset 6 x 3/8 in.	kit	Stanley	00671	41694	1
57 260 2754	Philips 2-4	kit	Stanley	02754	41694	1
57 260 2753	Pbilips 3-6	kit	Stanley	02753	41694	1
57 260 1009	Stubby 2 io.	kit	Stanley	01009	41694	1
57 320 1134	Scissors 4-in.	kit	Kleenk	113C-4	41694	1
34 111 0776	Solderiog iroo	kit	Ungar	000776	41694	1
34 110	Soldering gun	kit	Wen	000100	41694	1
57 130 0111	Tool, crimpiog	kit	T B	0W-111	41694	1
34 190 0555	Torch, propane	kit		LP-555	41694	1
57 040 3597	Tube extractor	kit			41694	1
57 330 5191	Tuhe pin strtnr	kit		5191	41694	1
57 330 8105	Tuhe pio strtnr	kit		8105	41694	1
57 070 0100	Wire strippers	kit			41694	1

Geotech Catalog No.	Description		Mfr	Part No.	Contract No.	Quao
	Wreoches					
60 000 0001	Alleo bex	kit	Holcrom	00044	41694	1
57 210 4932	Box 1/4 x 9/32	kit			41694	1
57 210 1638	Box 5/16 x 3/8	kit			41694	1
57 210 8716	Box 3/8 x 7/16	kit			41694	1
57 210 1618	Box 1/2 x 9/16	kit			41694	1
57 230 0104	Cresceot 4 in.	kit		AC104	41694	1
57 230 0106	Crescent 6 in.	kit		AC106	41694	1
57 230 0110	Crescent 10 in.	kit		AC110	41694	1
57 230 0112	Cresceot 12 io.	kit		AC112	41694	2
90 11746 00	Exteo alleo 1/32	kit	Geotech	11746	41694	1
90 11739 00	Exten alleo 1/16	kit	Geotech	11739	41694	1
90 11743 00	Exten allen 3/64	kit	Geotech	11743	41694	1
	Pipe plg 1/2 sq	kit			41694	1
	Ratchet 15/8-3/4				41694	2
60 000 0002	Socket set sml	kit	Oxwall		41694	1
90 10501 00	Socket, long	kit	Geotech	10501	41694	1
	Socketset	kit			41694	1
	Misc. Tools					
60 000 0003	Chest, tool	kit	Kennedy	00K2O	41694	1
	Compass, eogr	kit			41694	1
5 0050	Cord, exto 50 ft	kit			41694	1
	Demagnetizer hd	kit	Allied		41694	1
49 102 1077	Gage, tire	kit	Sears	9A4472	41694	1
49 000 0606	Oiler, pump	kit	Glonrod	000606	41694	1
	Saw, skill 8 io.		Skill	000858	41694	1
69 160 0325	Scale, oz. 2 lh	kit	Chatilo	00325	41694	1
60 000 0004	Set, ignition	kit	Sears	9A44671	41694	1
62 140 5816	Trouble light	kit	Sears	34A5816	41694	1
57 290 7767	Vise, clamp 3 io	kit		776B	41694	1
66 300 3107	Watch, stop	kit	Sprtcft	03107	41694	1
	Weight kit cah	kit		18-PA	41694	1
	Minor Plant Equipment					
	Blanket furnit	mpe			41694	2
	Cart, scope	mpe	Atlants		41694	1
	Chair, swivel	mpe	Casco	00155	41694	1
81 203 0002	Cooler, water 2 gal.	mpe			41694	1
73 004 6810	Heater, hot pl	mpe	Sears		41694	1
55 040 0006	Ladder, step 6 ft	mpe			41694	1
49 101 1213	Pump, foot	mpe	Sears	28A1213	41694	1
71 400 1786	Stool, adj	mpe	Lyoos	01786	41694	1
71 400 1701	Stool, stl 18 in	mpe	Lyons	01701	41694	1
	Tarpolin 10 x 10	mpe			41694	1
	Telephone, Field	mpe			41694	1
	Telephone, vao	mpe	Geotech	10232	41694	1
67 500 1208	Timer, GE, photo	mpe	Genelec	E1208C	41694	1
	Fire ext.	mpe	General	00CP5	41694	2

APPENDIX 2 to TECHNICAL REPORT NO. 67-50

LRSM SPECIAL PRESENTATIONS GROUP
MAJOR EQUIPMENT INVENTORY

LRSM SPECIAL PRESENTATIONS GROUP
MAJOR EQUIPMENT INVENTORY

DIGITIZING EQUIPMENT:

Quantity	Description
1	Analog-Digital Converter: Applied Development Corp., 10-bit accuracy; 0.1, 1.0, 10, 25, 50, 100, 250, 500, 1000, and 10,000 samples/sec rates; used either online with digital computer or offline with Teletype BRPE 11 paper tape punch.
2	Digital-Analog Converter: Applied Development Corp., 10-bit accuracy; used online with digital computer.
1	Multiplexer: 10 channel, 10 kc rate.

ANALOG EQUIPMENT:

Quantity	Description
2	Tape Transports: Honeywell LAR7400; record and playback; 1-inch tape; 0.3, 0.6, 1.5, 3.0, 15.0, 30.0, and 60.0 in./sec.
1	Tape Transport: Ampex Model FR100B; read only; 0.3, 0.6, 30.0 and 60.0 in./sec.
1	Tape Transport: Ampex Model 306-7; record only; 30.0 and 60.0 in./sec.
5	Filters: Krohn-Hite Model 330A(R)-8; band-pass with upper and lower cutoff frequencies continuously variable; 6, 12, 18, and 24 dB/octave cutoff rates: 0.02-2,000 cps.
1	Analog Computers: EAI TR-10.
1	Recording Oscillograph: CEC Model 5-124; 7-inch light sensitive paper; 6 channels; 0.25, 1, 4, 16, 64 in./sec paper speeds.
1	Recording Oscillograph: CEC Model 5-119; 7- or 12-inch film or paper; 12 channels; 0.16-169 in./sec.

Quantity	Description
2	Helicorders: Geotech Model 2484.
1	Develocorders: Geotech Model 4000.
1	Magnetic Mirrograph: Techno Instruments Co., TI-401A; 8 channel.
2	Delay Line: AD-YU Electronic Lab, Inc.; Continuously variable delay; 1000 μsec max delay.
1	Time Encoder: Geotech Model 11667.
1	Time Code Tape Search Unit: Hyperion Industries, Inc.; Model HI-231V-B; VELA code only.
1	Oscilloscope-Record Camera: General Atronics, Model SM100; 35 mm film 59, 118, 295, and 590 in./min.
1	X-Y Recorder: Houston Instrument Corp., Model HR-95; 8-1/2 x 11 inch.
1	Spectrum Analyzer: Hewlett-Packard Model 302A; wave analyzer, used with Geotech spinning reproducer; 0-10 kc; 110 sec data maximum.

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13. ABSTRACT

The progress of the Long-Range Seismic Measurements Program (LRSM) during the period 1 April 1966 through 31 May 1967 is described. The data contained in the report are categorized along the same lines as the organization of the LRSM program; that is, operations, data processing, equipment modifications, equipment and seismogram evaluation, and special projects.

Sixteen mobile observatories and six portable systems were in operation during most of this report period. In January 1967, five of the mobile observatories were moved to Garland, Texas, and maintained on standby basis. The portable systems continued to be used extensively in a wide variety of seismic programs during this report period.

Several equipment modifications were incorporated into the standard system configurations: gas diode lightning protection systems were installed; an improved pen heat circuit was installed in the portable system Helicorder; ceramic stops were installed in the long-period phototube amplifier galvanometers; and the Timing Systems, Model 5400, were replaced in the LRSM vans with Timing Systems, Model 19000. New battery packs and voltage regulators were designed and installed in the portable systems, as well as an electronic voltage sensing circuit. In addition, a fire protection system was selected for installation in nine mobile observatories.

The equipment and seismogram evaluation programs continue to advance new and improved methods to ensure high quality data. The resulting data are being used for advanced methods of data processing. A review of the studies and evaluations made is included in this report. Studies have been undertaken and completed by the Special Projects group and include surveys of seismological bulletin data, effects of site geology and source medium on signal and noise properties, and characteristics and methods of processing long-period seismic data.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Long-Range Seismic Measurements Program						
VELA-Uniform						
Seismic Recording Systems						
Detection of Seismic Signals						